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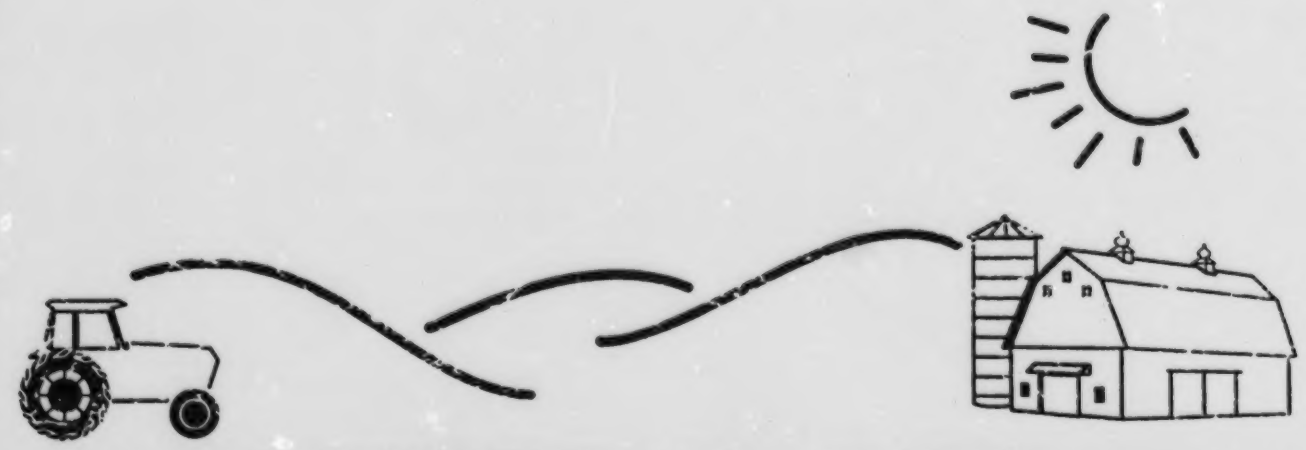
The University of Lethbridge

THE IMPACTS OF CLIMATE VARIABILITY ON AGRICULTURAL SUSTAINABILITY IN ALBERTA

The Impact of Climate Change on Agroclimatic Indices and Crop Yields



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Nat Christie Foundation Project:

The Impacts of Climate Variability on Agricultural Sustainability in Alberta

Final Research Report:

Impact of Climate Change on Agroclimatic Indices and Crop Yields

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We thank J.T. Kiniry, D.W. Stewart, J.T. Ritchie, C.O. Stockle, T.R. Sinclair, J. Tajek and the Nat-Christie Climate Change project team for their advice and assistance. The financial support of the Nat-Christie Foundation, Calgary, AB, is greatly appreciated.

E. EXECUTIVE SUMMARY

The increased production of greenhouse gases from fossil fuels is expected to result in significant climate change, particularly in the temperate and polar region. The magnitude of the effects on agriculture of the predicted change of 3 to 7°C could be very significant. The objective of this component of the overall Nat Christie Climate Change Project was to link weather data with crop simulation models and soils databases to assess climate change impact on crops. The procedures used were to evaluate a number of promising models, and select the most appropriate model. The second phase was to write computer scripts that would automate the process of running the model for a 50 x 50 km grid overlaid on some 800 soil landscapes. The simulations were conducted for spring and winter wheat and canola, in continuous and crop-fallow rotations. Irrigated corn and perennial grass was also run. Additionally, a seeding date model was developed to anticipate changes in seeding date brought about by climate change. A series of simple models describing growing degree days, frost free season, date of spring regrowth were also run. The EPIC model was chosen because it has the capability of simulating many crops and because it can simulate soil erosion, of interest in another component of the NC project. The results indicate that the future climate will support longer season crops throughout the province and that severe drought will be no worse than the current situation. There will be substantial shifts toward corn because of improved capability of growing warm season crops. Also, there will likely be shifts toward spring wheat when higher precipitation than current is considered. However, with the most adverse case of climate change scenario, winter wheat may be favoured as the early regrowth and reduced risk of winter kill will make this more profitable than spring wheat. In conclusion, the impact of climate change on agriculture could have a number of beneficial results, namely improved capability for diversification. However, this prediction should be tempered by the fact that there is considerable uncertainty in the estimation of future rainfall amounts and patterns.

Chapter I. INTRODUCTION

The agricultural industry in Alberta is complex, linking a land-based resource with consumers, processors and retailers. It consists of farms, a supply and services sector, processors, distributors, and transportation agents, and government participants. It also provides the basis for considerable employment and investment in the provincial economy. Environmental and economic sustainability is linked to the ąbility of the industry to understand the ecosystem and to adapt to changing conditions. Agriculture is highly dependent on climatic variation so the crops and cropping practices that have been adopted are based on the ability to secure reliable returns in most years. The economic viability of the agriculture enterprise depends on the ability to survive conditions that result in poor or non-existent harvests.

Southern Alberta, is particularly sensitive to climate variability and long-term change because it is a semi-arid region. Climate warming caused by changes in the chemical composition of the atmosphere are predicted to result in substantial warming. The average annual global temperature is expected to rise 1.5 to 4.5°C, and the variability, most notably in precipitation, will increase. Both of these changes will have a major impact on the provincial agriculture industry. The potential for increased severity and frequency of drought poses a threat to the viability of grain production in the region, and hence to the existing agricultural system. There is also concern that soil degradation and erosion may increase because of reduced soil moisture. How will our agricultural industry adapt to these changes? Irrigated areas will find increased demands for water from established parcels and new areas suffering severe drought. These increased demands may come at a time when river water, the principal source of irrigation water, may be declining due to a warming climate.

Problems with crop disease and pests may also increase. A warmer climate would allow diseases and pests that are currently constrained to lower latitudes to move northward. Longer growing seasons will give insects and diseases more time to multiply, creating more expansive infestations. Climate warming research predicts northern areas of the province will have a longer growing season, and an increase in overall productive potential. However, most of northern Alberta has poor quality soils that are not well suited to agriculture. The viability of the agricultural sector is currently threatened by drought, contamination of soil and water, soil degradation, decreasing effectiveness of pest control methods, and health risks from agri-chemicals. Agricultural markets are becoming more competitive, and margins are declining. International trade and subsidy issues have decreased agricultural viability and are making the agricultural industry more vulnerable to climatic variation. Reduced crop yields, soil erosion, and water shortages during drought years are

reminders of the relationship between the natural environment and social and economic conditions.

Assessing the viability of the agriculture sector is primarily concerned with the potential for assessing crop growth and its interaction with soils and pests, primarily insects and, if time and resources permit, diseases. This component of the Nat Christie project considered this from the point of view of assessing the main crops, spring wheat, canola, and grassland, and two crops which might increase, winter wheat and corn. These were considered for rain fed and irrigated production. The project, was an exercise in modelling a large number of complex steps and interactions to satisfy some simple objectives. In order to determine the most likely result of climatic variability and change, a mechanistic approach that combines proven models in a GIS setting was used.

Three critical components were involved; weather, crops and soils. Weather cannot be measured as a whole so it is quantified by measuring individual weather elements like air temperature or precipitation. Most instruments to measure weather elements were invented in the 17th and 18th centuries. The first practical thermometer was developed in 1641, the first barometer in 1643. An instrument to record global radiation was developed in the nineteen twenties. Air temperature data were recorded as early as 1659 in England but in most countries, however, the systematic recording of weather only started at the beginning of the twentieth century. Thus, the length of the weather record is relatively short.

There is enormous variation in weather in space and time. Air temperature, for instance, declines with increasing height while wind speed increases. Most weather variables show a time course over the day and year so when weather data from various sites are compared, it is essential that these data be recorded according to a certain standard. Basic standards of instruments and observing are practiced by those manning the network of weather stations. For instance, air temperature must be measured between 1.25 and 2.0 m height and the thermometer must be sheltered from radiation. Wind speed must be recorded at a height of 10 m. This standardization also includes the variables to be measured. Standards include air temperatures, dry- and wet-bulb, maximum and minimum and precipitation. The range can be extended with other elements, depending on the interest of the recording institute. It should be realized that weather data, even hourly data, do not give an exact description of the weather conditions. They only represent the values recorded by instruments on a moment at a particular site. The air temperature, measured at 1.25 m, gives not much information on temperature regime at soil surface.

Agricultural yields are strongly affected by the prevailing weather conditions during the growing season of the crop and considerable research has been invested in understanding the effects of weather conditions on crop growth and yield. Many initial attempts to relate yields to weather conditions used statistical methods such as multiple regression to relate average air temperature

and precipitation in various months to final yield. In general, a relation can be found only when a crop is very susceptible to the occurrence of one element during a certain growth stage. Several explanations can be given why it is difficult to find a relation between average weather and final yield. Crop yield is not determined only by weather conditions. Nutrient shortages and pests and diseases can also have a large effect on crop yield. Further, the yield of a crop is the integration of the seasonal weather. Weather elements are also related to each other. High temperatures occur often in combination with high radiation levels. This makes it impossible to determine whether the observed effect is caused by one variable or the other. Also, crops grown under current weather conditions experience large day to day variations. Consequently, monthly averages do not give an appropriate description of the growing conditions so the effects of weather on crops must be studied at a smaller time scale. The change from a monthly to a daily time scale leads to a 30-fold increase in the number of weather data required so the introduction of the computer in the early sixties made handling of these large amounts of data possible.

There is enormous variation in soils in space but relatively little in time relative to human memory. The soil is the medium in which the plant grows, providing water, nutrients and support. Tremendous research efforts over the past several decades have resulted in excellent soil maps of Alberta. In addition, recent efforts have been undertaken to relate soil characteristics to numerical inputs for crop models. There is an important spatial element to weather, however, the importance of spatial variation in soils is at least two orders of magnitude greater than for weather. For example, 10 regions might be sufficient to demonstrate the range of growing degrees but approximately 1,000 different soil polygons are used to illustrate the soil variability.

Since the early seventies computer models have been developed to simulate crop growth in relation to observed weather conditions. These models integrate our knowledge of the most important effects of weather and soils on individual crop growth processes such as global radiation, air temperature and soil moisture. These models have made it possible to study the effect of weather on crop yield. Since the final yield of a crop is determined by weather, crop cultivar, fertilizer, soil, and pests and diseases it is difficult to accurately quantify all of these effects. In crop modeling research several scenarios can be distinguished. The crop can be supplied with optimal amounts of water and nutrients and be free from pests, diseases and weeds so crop growth is only determined by crop characteristics, temperature and radiation. In other scenarios the crop can be limitied by water, nutrients, pests, diseases or weeds.

Crop growth simulation models are used as tools to understand the observed phenomena in field experiments or to quantify growing conditions in survey studies and they usually operate with a one day time interval and require daily weather data. However, weather data used as input for

crop growth models are often accepted at their face value. Storing meteorological data in convenient data bases ensures that most users never see the original data with its unrealistic or missing values, so no feeling for quality of the data is developed. Weather data, however, are not error free nor do they give a precise description of the real weather conditions. Similarly, when evaluating simulation models, it is difficult to acquire a record of crop performance that is suitably long and sufficiently detailed. All farmers and field crop researchers know that growing crops is a life-long learning experience and each year the crop responds somewhat mysteriously to unkown factors. Thus, the evaluation of a crop model can only be measured against the modeled and measured parameters. The consequence of this is that many environment-year combinations, perhaps twenty five or fifty, may be required simply to obtain a good estimate of the mean. Consequently, in crop modeling output it is important to know whether the difference between the observed and simulated growth was caused by the errors in weather data, errors in measurement of the crop response or if it was due to incorrect simulation of crop growth.

Several sources of irregularities in weather data can be distinguished. There is inaccuracy of the instrument, missing values due to break down of instruments or to problems with the data collecting computer. Crop growth models require data for every day, so the values of the missing data have to be estimated. Another source of errors is that meteorological data are recorded at a limited number of sites so the distance between the weather station and the experimental site may mean that weather conditions are not the same. Global radiation includes both direct and diffuse solar radiation and is an important weather factor for agricultural research, since this type of radiation provides the energy for crop growth. Since the sixties the number of sites where global radiation is recorded has increased, but presently global radiation is still measured at only a small number of meteorological stations. In some countries different networks exist. The fact that long period records of global radiation only exist at a few sites and that even now this variable is recorded at only a few sites makes global radiation the limiting factor in most weather data sets. Fortunately, the spatial variability of solar radiation is not as great as for temperature or precipitation. Sunshine duration (hours of bright sunshine per day) is recorded at more locations than global radiation. Sunshine duration and the amount of global radiation are related so sunshine duration data are often used to estimate the global radiation.

One of the characteristics of precipitation is its very irregular distribution in space and time. Differences in water deficit will affect the sensitivity of the simulation model to inaccuracies in certain weather data. When enough water is available, errors in evapotranspiration are not likely to affect the final yield but in dry years an accurate calculation of evapotranspiration is vital for a good simulation of crop production. So the sensitivity of the model to inaccuracies in precipitation will

differ from year to year. The Meteorological component of the Nat Christie Climate Change Project has developed the most comprehensive database to date of Alberta. Careful examination of the raw data revealed the existence of poor quality and missing data. The best available algorithms were then used to estimate missing values where appropriate. Since the consideration of spatial variablility was so important to this study, algorithms were developed to produce a fine grid of weather data for the province at approximate 50 km spacings. As a result, this project was able to utilize the most error-free weather data possible. At those points in Alberta where the scarcity of weather stations was most extreme, primarily in northern Alberta, it was not possible to simulate crop growth. Since these areas currently are not important agricultural areas and since the soils are generally poor, this was not viewed as a serious limitation.

Presently for major crops like wheat, maize, etc. well developed crop growth simulation models exist (Ritchie & Otter 1984, Jones & Kiniry 1986, van Keulen & Seligman 1987, Spitters et al. 1989). The overall effect of weather conditions on crop production is rather ambiguous. The effect of, for instance, high radiation levels at high temperatures can differ considerably from the effect at low temperatures. In studies involving the effect of weather conditions on crop yields, simulation models can serve as a tool since weather-crop growth relations are quantified in them. In the last years several studies have been published in which crop growth models were used to quantify growing conditions of crops. Examples are studies on production possibilities in various regions of the world (van Keulen & de Milliano 1984, Hodges et al. 1987, van Keulen et al. 1987, Aggarwal & Penning de Vries 1989, van Diepen et al. 1990, Lopez-Tirado & Jones, 1991), or on the effects of climate change on crop production (Wilks 1988, Adams et al. 1990, Cooter 1990, Jansen 1990). When existing crop growth models are used for such large scale type of research, problems often occur with respect to availability of required input data. Daily weather data are seldom available. Therefore in land evaluation studies weather data are generated from average values or averages are used (van Keulen & de Milliano 1984, Aggarwal & Penning de Vries 1989, van Diepen et al. 1990, Lopez-Tirano & Jones 1991). Because weather-crop growth relations in models are often non-linear, simulation results with average input data can deviate from average simulation results with daily data. The use of crop growth models in this large scale type of research is likely to increase in the future; it is therefore important to analyse the effects of using average weather data on the simulation results of these models.

Increasing atmospheric $C0_2$ concentration can affect agricultural production in two ways. On the one hand a higher $C0_2$ concentration has a stimulating effect on photosynthesis (Lemon 1983, Cure & Acock 1986) and leads to improved water use efficiency of crops (direct effect, Gouddrian & van Laar 1978b, Gifford 1979, Sionit et al. 1980). On the other hand, being a greenhouse gas,

increasing $C0_2$ can induce climatic change (indirect effect). In the last decade a large body of research has been conducted on the effects of increasing $C0_2$ concentration on crop production, varying from indoor $C0_2$ enrichment experiments with individual plants (Kimball 1983, Acock & Allen 1985) to modelling the effects of climatic change on crop production in various parts of the world (Rosenzweig 1985, Parry & Carter 1989). A limited number of studies exists in which the combined effects of increased CO_2 concentration and climatic change on crop production is investigated. Jansen (1990) studied the combined effect of $C0_2$ concentration rise and climatic change on rice production in Asia and Adams et al. (1990) the effect on production of wheat, maize and soybean in the United States.

Two important questions had to be answered. What model is most suited to the objectives of this study? How well do the models perform. To answer the first question, we attempted to evaluate as many regionally adapted models as possible. These included the Canadian Prairie "Stewart" model developed by Stewart and Dwyer of Agriculture Canada, one of the original wheat models, the Crop Estimation through Resources and Environment Synthesis, "CERES" developed by Jones and Ritchie at Temple, TX, the Erosion Productivity Impact Calculator, "EPIC" developed by the USDA at Temple, TX, the "Century" soil carbon model from Colorado State University, and the simple "Sinclair" model developed by Tom Sinclair from Florida.

An excellent wheat database for Alberta was available from the "ABC Rotation" grown continuously at the Lethbridge Research Station since 1911. This included wheat, wheat-fallow, and wheat-wheat-fallow rotations. In addition, a cooperative winter wheat study, rainfed and irrigated, with comprehensive plant measurements was available for Lethbridge, Mandan, SD, Mead, NE, Manhattan KS and Lubbock TX. The data from these two studies provided the baseline from which to select the most appropriate model for climate change simulations. In addition, an extensive body of literature has built up in the past five years in which these and similar models have been tested and used in similar projects in other regions, providing a degree of confidence for the decisions that were necessary.

In the Stewart model an empirically based set of algorithms is used to estimate hard red spring wheat production on a crop reporting district basis. A simple linear analog is used to calculate plant water stress and a nonlinear response factor for temperature effects are the main factors controlling growth simulation. Empirical relationships are used to quantify the effects of soil type, management and time trends.

In the basic CERES model, crop development is driven by temperature and photoperiod, and controls partitioning of carbon. Phytomass accumulation, driven by solar radiation and moisture availability (and to a lesser degree, temperature) determines yield, both grain and whole plant.

Cultivar differences are modelled by modifying the appropriate coefficients relating development and photosynthesis to environmental parameters. It is well known that climate has a major influence on crops grown and associated soil management (irrigation, tillage, seeding, fertilization, etc.) practices in a particular region. Similarly, it is well documented that crop rotations and tillage practices can have a major impact on soil quality and productivity. Therefore any change or increased variability in climate could have a major effect (positive or negative) on the sustainability of our soil resource.

In the EPIC and CENTURY models net primary productivity along with farm management is used to estimate long term changes in soil organic matter. We propose to utilize these models to assess soil quality and productivity as affected by climate change and its associated implications on, soil conservation and factors affecting soil productivity. EPIC (Erosion Productivity Impact Calculator) simulates the behaviour of physical components (eg. hydrology, weather, erosion, nutrient cycling, plant growth, tillage, and soil temperature) which in turn aid in the calculation of the economics of soil erosion. Within EPIC, a single model is used to simulate crop growth (eg. wheat, corn, canola, etc.). Plant biomass is calculated using various parameters such as: heat units, leaf area index, photosynthetic active radiation, day length, and harvest index. Potential plant biomass is adjusted daily according to the relative influence of stress factors such as water, nitrogen, phosphorus, and oxygen. CENTURY uses similar information as EPIC to calculate soil organic matter and other soil quality characteristics in various 100-year options depending on crops grown and different climatic variables.

In the Sinclair model a very simple relationship between radiation use efficiency and leaf area index is used to simulate biomass production. Temperature and soil moisture are the factors driving leaf area development. Thermal time controls development.

The main crops grown in Alberta are cereals, led by hard red spring wheat, oilseeds (mainly canola) and forage crops, mostly rangeland. Climate warming will likely result in more winter wheat and expansion of area seeded to warm season crops such as corn and beans. Consequently the crops chosen for detailed simulation in this study were spring wheat, canola, winter wheat, corn, and crested wheatgrass. No tillage effects were simulated and the rotations were either continuous or crop-fallow. Figure 1 presents the diagram flow of the modeling approach used for the overall study based on 166 weather grid points (Figure 2) and Figure 3, Alberta Crop Reporting Districts.

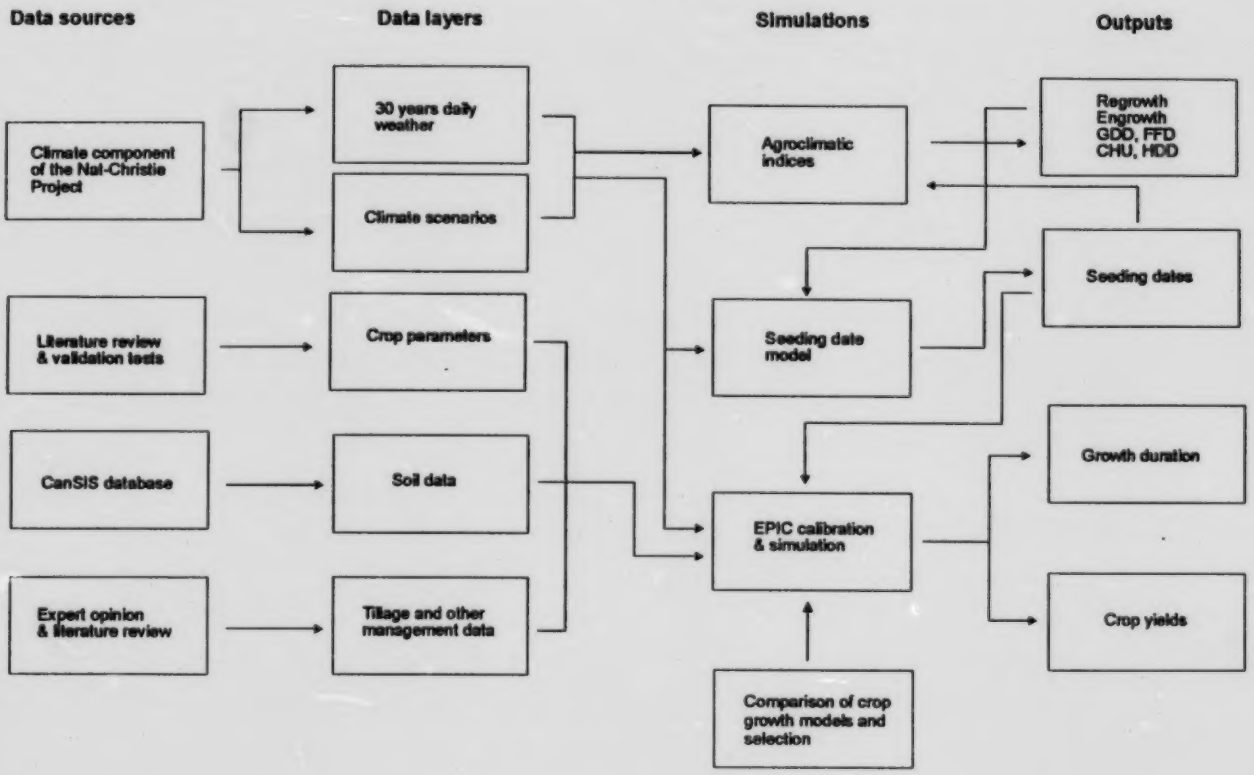

Figure 1: Diagram flow of the modeling procedure

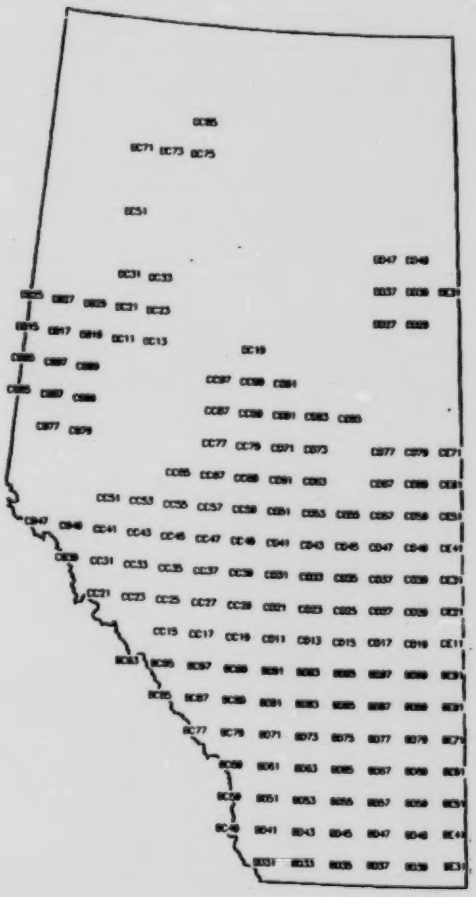

Figure 2: Location of the 166 weather grid points with complet data set across Alberta.

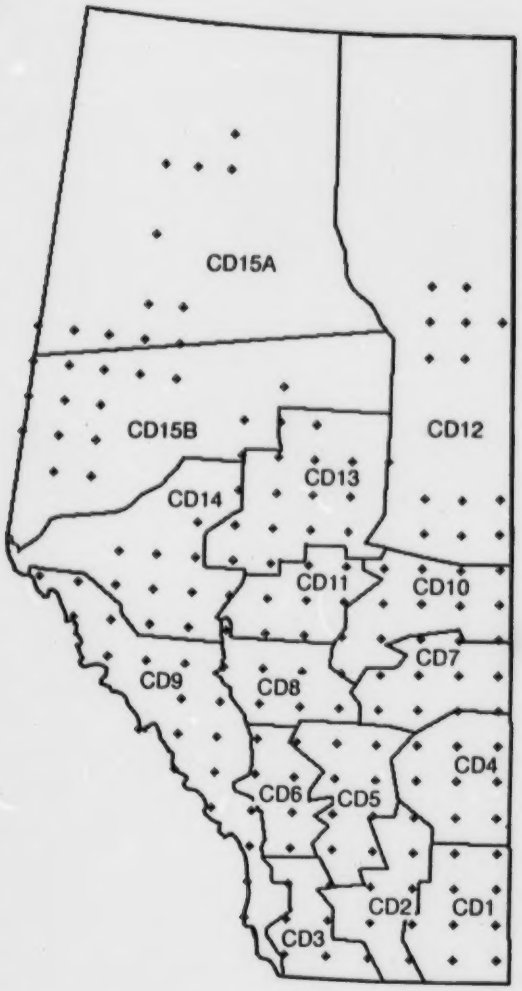

Figure 3: Alberta Crop Reporting Districts

Comparison of five wheat simulation models in southern Alberta

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Touré, A., Major, D. J. and Lindwall, C. W. 1994. **Comparison of five wheat simulation models in southern Alberta.** Can. J. Plant Sci. 75: 61–68. Increasing concentrations of greenhouse gases are expected to result in global warming which will affect crop production. Crop modelling is a useful tool for assessing the impact of climate change on crop production. The objective of this study was to select an appropriate model for climate change studies. Five simulation models, EPIC, CERES, Century, Sinclair and Stewart, were assessed using data from a long-term experiment begun in 1911 on a clay loam (Dark Brown Chernozem) soil at Lethbridge, AB. Yields predicted by the five models were compared with actual spring wheat yields in continuous wheat, fallow-wheat and fallow-wheat-wheat rotations. The EPIC model gave the best simulation results over all rotations and the most accurate predictions of mean yields during droughts. It was concluded that the EPIC model had the greatest potential for assessing the impact of climate change on wheat yield. The Stewart model was the most accurate for unfertilized continuous wheat and fallow-wheat. The Sinclair model was most accurate for fertilized fallow-wheat and CERES was the most accurate model for fertilized continuous wheat. The Century model simulated average yield accurately but did not account for year-to-year variability.

Key words: Global warming, crop simulation, spring wheat yields

Touré, A., Major, D. J. et Lindwall, C. W. 1995. **Comparaison de cinq modèles en simulation de culture du blé dans le sud de l'Alberta.** Can. J. Plant Sci. 75: 61–68. L'accroissement des concentrations de gaz à effet de serre devrait conduire à un réchauffement à l'échelle planétaire qui influera les productions végétales. La modélisation des cultures est un outil utile pour évaluer les impacts des changements climatiques sur les cultures. L'objet de notre étude était de choisir un modèle convenable pour les travaux sur les changements climatiques. Cinq modèles en simulation EPIC, CERES, Century, Sinclair et Stewart ont été évalués à partir des données d'une expérience de longue durée mise en place en 1991 dans un loam argileux (chernozem brun foncé) à Lethbridge (Alberta). Les rendements prédits par les cinq modèles ont été ensuite comparés avec les rendements réels de blé de printemps obtenus dans les assolements blé en continu, jachère-blé et jachère-blé-blé. C'est le modèle EPIC qui a fourni le meilleur résultat en simulation, tous assolements confondus, ainsi que les prédictions de rendements moyens les plus justes lors des épisodes de sécheresse. Ce modèle apparaît donc comme le plus approprié pour l'évaluation de l'effet des changements du climat sur le rendement du blé. Par ailleurs, le modèle Stewart était le plus fidèle pour les assolements blé en continu et jachère-blé sans fumure, tandis que le modèle Sinclair convenait davantage pour l'assolement jachère-blé avec fumure et le modèle CERES pour le blé en continu avec fumure. Le modèle Century prédisait fidèlement le rendement moyen, sans toutefois tenir compte de la variabilité du rendement d'une année à l'autre.

Mots clés: Réchauffement planétaire, simulation des cultures, rendement, blé de printemps

Crop growth is a complex combination of crop responses to weather and the soil conditions. There are at least 14 wheat models (Global Climate and Terrestrial Ecosystems 1992) which attempt to account for the physiological processes that govern wheat growth and development. Some of these are simple empirical models while others are complex mechanistic models. Many of the empirical models are based on regression equations developed using data collected at a single site or region. Such models may provide accurate simulation but they are restricted to the environment under which they were developed and have no cause and effect mechanisms. Mechanistic models use complex equations, some of which may be empirical, to describe the physical and physiological processes that control crop growth and development (Ritchie and Otter 1985; Williams et al. 1990; Stockle et al. 1993). Most mechanistic models use phenology to partition photosynthate, the amount of which allows growth prediction. Phenology is controlled mainly by temperature and photoperiod while growth is controlled by temperature and moisture (Major and Kiniry 1991). Modelling should enhance our understanding of crop growth and development in a changing climate; however, the selection of the appropriate model or combination of models requires careful attention to validation and tailoring of the model to the intended purpose.

The main features of five widely-used wheat simulation models are presented in Table 1. The Crop Estimation through Resources and Environment Synthesis (CERES) wheat model was one of the first crop models to provide a description of wheat growth and development over wide geographic areas. The universality of CERES is due, in part to a descriptor which allows the incorporation of the genetic

Abbreviations: **CERES**, Crop Estimation through Resources and Environment Synthesis; **EPIC**, Erosion Productivity Impact Calculator; **RUE**, radiation use efficiency; **TU**, thermal unit

Table 1. Qualitative comparison of the five models

Model	Advantages	Disadvantages
CERES	Detailed model	Many input parameters Single crop simulation
EPIC	Detailed model Weather simulation Multi-crop simulation Erosion prediction	Many input parameters
Century	C,N,P,S dynamics Soil carbon monitoring Multi-crop	No annual weather input Low output frequency
Stewart	Simple model Few input parameters	No fertility effect Single crop
Sinclair	Simple model Few input parameters	No fertility effect Single crop

response to soil and climate. The Erosion Productivity Impact Calculator (EPIC) (Williams et al. 1990) was developed to describe crop growth and development by focusing on the relationship between soil erosion and productivity and extending the model to cover many crops. Although, EPIC and CERES use different algorithms to treat growth and development, their input and output variables are similar. Both require daily values for temperature, solar radiation and precipitation. The EPIC model can also use wind speed to simulate soil erosion.

The Century model was created to study soil carbon, nitrogen, phosphorus and sulphur cycles rather than crop yields (Parton et al. 1988). It was intended to simulate grassland, savannah and forest ecosystems, and has been extended to agricultural cropping systems. Grain yield, predicted from carbon allocated to grain, was not intended to be a strong point of this model, which has evaluation of long-term soil change as its main purpose. The Sinclair model was an attempt at simplification. It is based on radiation-use efficiency (Sinclair and Amir 1992) and includes only a few relationships to define leaf-area development as a function of temperature, biomass accumulation as a function of intercepted radiation, and calculates kernel growth from a linear relationship between harvest index and time.

The models described above were developed with experimental data from many locations, particularly in the USA, and have been validated with independent test plot data over range of environments (Wagar et al. 1986; Williams et al. 1989; Sinclair and Amir 1992; Moulin and Beckie 1993).

The Stewart model was designed to calculate hard red spring wheat yields in western Canada on a crop district basis (large area). A simple resistance analog is used to calculate plant water stress and a nonlinear response factor for temperature effects (Stewart and Dwyer 1990). Effects of soil type, management practices and time trends unrelated to weather were expressed using relationships unique to western Canada.

The objective of this study was to select a model suitable for describing spring wheat growth on the Canadian prairies in order to evaluate the impact of climate change on crop productivity.

Table 2. Phenological coefficients for CERES and Sinclair models

	CERES	Sinclair
Vernalization (P1V)	0.2	
Photoperiodism (P1D)	1.0	
Terminal Spikelet to anthesis		460 TU
Duration of anthesis		90 TU
Grain filling (P5)	1.5	550 TU
Kernel number (G1)	1.5	
Kernel weight (G2)	1.6	
Spike number (G3)	1.0	
Single leaf growth (PHINT)	85 TU	80 TU

MATERIALS AND METHODS

Field Data

The database used to evaluate spring wheat yield prediction of the five models was from the long-term dryland spring wheat 'ABC' rotation initiated in 1911 at the Lethbridge Research Station (Longitude: 112°50′W, Latitude: 49°42′N) and described in detail by Dormaar (1983). In this experiment, the effect of cropping frequency on grain yield and soil quality of a clay loam soil (Dark Brown Chernozem) was monitored. The rotations were continuous wheat, fallow–wheat and fallow–wheat–wheat. No fertilizer was added until 1967 when each of the rotations was split to include two levels of nitrogen (0 and 45 $kg \cdot ha^{-1}$).

From 1912 to 1990, a number of wheat varieties were seeded at a rate of 60 kg ha^{-1} and at dates ranging from early April (1913) to early June (1967). Cultivars used were Red Fife from 1911 to 1917, Marquis from 1918 to 1950, Rescue for 1951 and 1952, Chinook from 1953 to 1969, Neepawa until 1973, Cypress for 1974 and 1975, Canuck in 1976, Chester until 1982 and Lancer until 1990. Details of cultural and fertilizer practices were presented by Janzen et al. (1993). Significant eras in the rotation's history included horses until about 1944; in about 1955 wild oats became such a problem that seeding dates were delayed until 20 May to allow a pre-seeding cultivation; the introduction of Avadex in 1962 permitted a return to seeding dates in early May.

The soil characteristics and soil moisture at planting, required by the models, were obtained from Janzen et al. (1993) and Chang et al. (1990). Weather data were taken from the Lethbridge Research Station weather database. These data came from a weather station operated within 500 m of the rotation site during the period of study.

Models' Input

The crop parameters required varied with the model. For the EPIC simulation, the requirements followed Stockle et al. (1992) and Kiniry et al. (1994, EPIC model parameters for crops and forages in the northern Great Plains of the U.S. and the prairie Provinces of Canada, pers. commun.). The biomass-energy ratio or radiation use efficiency (RUE) for 330 ppm CO_2 was set at 3.1 g MJ^{-1} and maximum root depth was set at 1.2 m. The genetic coefficients for CERES and the thermal units (TU, mean of maximum and minimum temperature above a base of 0°C) for the Sinclair model (Table 2) were determined using an iterative process.

This was done by running the models with input data and approximate genetic and TU parameters for CERES and Sinclair models, respectively, comparing the output with actual phenology and yield data for a randomly selected year in the data sets and then changing the parameters until the calculated and measured values fit. Coefficients for the five growth stages in the Stewart model were already defined using a biometeorological time scale (Stewart and Dwyer 1990). The EPIC model, because of its less-detailed crop phenological phase, requires only the potential heat units needed for the maturation of crop. This value may be input or calculated by the model from normal planting and harvest dates. As with EPIC, the Century model requires seeding and harvesting dates for wheat and a harvest index. The maximum potential productivity was set at 900 g m^{-2} and the carbon content of the grain was set at 43%.

With respect to the Sinclair and Stewart models, continuous and fallow wheat rotations were simulated based on the soil moisture differences at planting dates. Fallow wheat plots have a higher soil moisture at planting than continuous wheat. A difference of 69 mm (Chang et al. 1990) was used to run the Sinclair model while the Stewart simulated the soil moisture for the two rotations at planting dates.

In the Stewart model, yields of wheat seeded into summerfallow (Y_f) and into stubble (Y_s) were calculated. This model was intended to simulate wheat growth under the technological conditions used in the 1960s so effects of that technology were compensated for by regressing the difference between actual and calculated yields against the time from year 1961 (Stewart and Dwyer 1990). For our study, a time function was generated using local wheat yields from 1960 to 1990 [time (t) = 1 for 1961 and 0 before 1961]:

$$F(t) = 9.19*t - 0.156*t^2 \quad (1)$$

where t is in years and $0 < t < 30$.
This function was used to calculate the final yield as follows:

$$Y_{tf} = Y_f + F(t) \quad (2)$$

$$Y_{ts} = Y_s + F(t) \quad (3)$$

where Y_f and Y_s are yields of wheat seeded into summerfallow and onto stubble, respectively, as calculated by the basic model, and Y_{tf} and Y_{ts} were adjusted for local time trends. The other models (CERES, EPIC and Century) consider the technological term through the management options which include crop type, fertilizer application and tillage practices.

Four of the five models were run using observed daily data for solar radiation, maximum and minimum temperature, and precipitation. Missing solar radiation was estimated using an empirical relationship between incoming solar radiation, precipitation and the day of the year. The Stewart model uses only maximum and minimum air temperature and precipitation and calculates daily solar radiation at the top of the atmosphere to compute potential evapotranspiration. In addition to using daily weather parameters, EPIC can generate the daily parameters from monthly weather statistics. The Century model generates its own weather data, based on means and variances of a sample input of weather data. For the purposes of this study, the average monthly values for each of the years were used to run Century for 20 yr and the mean yield was averaged as Century's predicted yield. This was necessary since Century is designed to be run for long sequences of years.

Selection of the Model(s)

In addition to using long-term data to evaluate the models, drought event simulation was considered. Climate change is likely to include extreme weather events (Drenmem and Kaiser 1993) so it is important that simulation models portray these events realistically. The decade 1929–1938 and the years 1961 and 1984 are representative drought periods at Lethbridge. During these years, droughts were severe and reduced crop yields considerably (Williams et al. 1988).

Evaluation of the models was based on a simple linear regression method and the accuracy analysis described by Allen and Raktoe (1981). The latter divides the regression error of the simulation into bias, regression and random errors. Bias error is associated with a failure to accurately account for range of the data and regression error represents a failure of the model due to curvilinearity for example. Both methods were used in order to provide a means of selecting the model which had the most significant relationship between actual and predicted yield, most accurately predicted the mean yield, and produced the lowest bias (U^m) and regression (U^r) errors.

RESULTS AND DISCUSSION

Long-term Simulation (1912–1990)

With respect to all of the rotations (Tables 3–7), the Century model results were not significantly correlated with the data set, although the mean yield was reasonably well predicted.

CONTINUOUS WHEAT. The highest correlation coefficient for continuous wheat receiving no fertilizer was produced by the Stewart model, followed by CERES and EPIC (Table 3 and Fig. 1). The CERES and EPIC models had similar correlation coefficients and slopes. All of the models had slopes that ranged between 0.30 and 0.65, which was a cause for concern since it suggested that none of the models adequately accounted for extreme years. The EPIC model, with similar coefficient of determination to CERES, had a lower mean yield difference (8 versus −41 g m^{-2}) and a higher proportion of error attributable to random variation. This implied that it was more accurate than CERES in predicting mean wheat yield. The Sinclair model consistently overestimated the actual yield (MD = −106 g m^{-2}, U^m = 0.58). The high bias error was likely related to the fact that nitrogen inputs were not taken into account.

Continuous wheat grown with nitrogen (Table 4) was most accurately simulated by CERES (r = 0.73, b = 0.94) and EPIC (r = 0.77, b = 0.44). However, the regression error was higher (70% of the errors) for EPIC than for CERES suggesting that adjustment may improve the model capability. Both models predicted the actual mean yield accurately

(MD = 2 g m^{-2} for EPIC and 7 g m^{-2} for CERES). The Sinclair model performed better when used to simulate fertilized rather than the unfertilized continuous wheat (MD = −29 g m^{-2} and r = 0.56).

FALLOW-WHEAT. Yields predicted using the Stewart model showed the best correlation (r = 0.75, b = 0.94) with the unfertilized fallow-wheat rotation yields (Table 5). The EPIC model, with lower correlation coefficient (r = 0.39) and slope than the Stewart model predicted actual mean yield with better accuracy (MD = 21 g m^{-2}) than the Stewart model. The Sinclair model consistently overestimated yields with high bias and regression errors.

The Sinclair model produced the best simulation for the fertilized fallow-wheat rotation (Table 6). However, the EPIC model performed reasonably well (r = 0.71, MD = 29 g m^{-2}, U^c = 27%).

FALLOW-WHEAT-WHEAT. Century and EPIC were the only models with the capability of simulating crop rotations. For the fallow-wheat-wheat rotation, EPIC performed better under both fertility regimes (Table 7). Actual and predicted yields were related significantly and mean yields were simulated accurately. As with EPIC, Century predicted average yield that was similar to actual mean yield but there was no correlation with the dataset.

OVERALL SIMULATIONS. Averaged over rotations, Century predicted mean yield with good accuracy, but was unable to account for year-to-year variation. This was probably due to the method used in the model to handle weather data. Century uses monthly mean temperature and precipitation from which it generates weather statistics.

Simulations of wheat rotations that received nitrogen were more accurate reflections of observed than were those without nitrogen, partly because there were fewer years in which fertilizer was applied. However, the variability due to weather was not well simulated by any of the models. The intercepts were all high and slopes were low, suggesting that all the models will result in an underestimation of variability in a changing climate.

Our results are similar to those of Moulin and Beckie (1993), who found that EPIC and CERES underestimated yield in high-yielding environments and overestimated yield in low-yielding environments. They obtained low correlation (r = 0.40 and 0.41, respectively) and slope (0.38 and 0.50, respectively) for EPIC and CERES by regressing seasonal simulated yields against 30 yr (1960–1989) of observed yields in Melfort, SK. Higher correlation coefficients were obtained by Mearns et al. (1992) (r = 0.62) and Fei and Ripley (1988) (r = 0.70) using CERES-wheat model with crop data from the USA and Canada, respectively, which is similar to our fertilized continuous wheat simulation

Table 3. Statistics derived from linear regressions and accuracy analysis relative to unfertilized continuous wheat rotation (n = 79)

Actual mean yield (A) = 97 g m^{-2}

Parameters	EPIC	Century	CERES	Stewart	Sinclair
Predicted mean yield (P_i)	89	87	138	124	203
Mean difference (MD = $A-P_i$)	8	10	−41	−27	−106
Intercept (a)	52	126	23	16	38
Slope (b)	0.50*	−0.30	0.53*	0.65*	0.29*
Correlation coefficient (r)	0.51	−0.17	0.54	0.65	0.45
Bias error (U^m)	0.01	0.02	0.31	0.21	0.58
Regression error (U^r)	0.25	0.31	0.16	0.14	0.25
Random error (U^c)	0.74	0.60	0.53	0.65	0.17

$U^m = (P_i-A)^2/[\Sigma(P_{ri}-A_i)^2/n]$.
$U^r = (S_p-rS_a)^2/[\Sigma(P_{ri}-A_i)^2/n]$.
$U^c = (1-r^2)S_a^2/[\Sigma(P_{ri}-A_i)^2/n]$.
$S_p^2 = \Sigma(P_{ri}-P_i)^2/n$.
$S_a^2 = \Sigma(A_i-A)^2/n$.
* Significant at P = 0.05.

Table 4. Statistics derived from linear regressions and accuracy analysis relative to fertilized continuous wheat (n = 24)

Actual mean yield (A) = 146 g m^{-2}

Parameters	EPIC	Century	CERES	Stewart[z]	Sinclair
Predicted mean yield (P_i)	139	160	144		175
Mean difference (MD = $A-P_i$)	7	−14	2		−29
Intercept (a)	84.7	83	10.6		53
Slope (b)	0.44*	0.40	0.94*		0.53*
Correlation coefficient (r)	0.77	0.26	0.73		0.56
Bias error (U^m)	0.01	0.03	0.00		0.14
Regression error (U^r)	0.70	0.15	0.01		0.23
Random error (U^c)	0.29	0.82	0.99		0.63

[z] Rotation not simulated.
* Significant at P = 0.05.

($r = 0.73$). The Century model has been validated in Canada using 5 yr of average spring wheat grain biomass and the mean yields were simulated reasonably well (Wagar et al. 1986). With the Stewart model, Stewart and Dwyer (1990) obtained $r = 0.88$ with mean yield simulated reasonably well. Their results were better than those in this study since the model was calibrated using the Canadian crop district data on which their validation was based. Compared with our result, Amir and Sinclair (1991) obtained a similar slope (0.55) but a better fit ($r = 0.75$) by regressing the Sinclair model output against 10 yr of high yield data (high irrigation and nitrogen fertilizer) from Gilat, Israel. The difference in the two studies may be because the model assumes that the crop is grown under optimum conditions, which was the case in Gilat.

The prediction of higher-than-actual yields in unfavorable seasons and lower-than-actual yields in high-yielding environments is a shortcoming of all of the models. One of the impacts of climate change could be increased variability so it is critical that crop models predict the full range of yield possibilities.

Drought Events Simulation (1929–1938, 1961 and 1984)

The unfertilized 'ABC' rotations were used for this analysis since most of the droughts occurred in years before fertilizer application began in this experiment. Also, less fertilizer is applied in dry years since farmers fertilize according to spring soil moisture (Bole and Pittman 1980). Climatic parameters for the drought events were compared with the average for the 79 yr of the experiment (Table 8). The extreme years selected for the analysis had 8 mm lower precipitation and 0.26 and 0.5°C higher minimum and maximum temperatures, respectively, during the growing period (March to August). Solar radiation was similar in the two data sets. A 55% yield reduction was observed for continuous wheat, 18% for fallow-wheat and 25% for fallow–wheat–wheat.

The simulation models showed no significant relationship between actual and predicted yields (Tables 9–11) in these extreme years. All the models underestimate or overestimate mean yields for the different rotations. The EPIC model, however, produced a mean predicted yield that was closer to the mean actual yield than any of the other models; MD = −10, 14 and −19 g m^{-2} for continuous wheat, fallow-wheat and fallow–wheat–wheat rotations, respectively.

CONCLUSIONS

The choice of a single model for predicting the effect of climate change on wheat production in western Canada is difficult based solely on the yield predictions for the long-term rotation experiment at Lethbridge. This rotation provides a valuable record of interannual yield variability for three important rotations in western Canada. All five of the models predicted average yield estimates for the three rotations, and all five failed to account for the full range of yield variability.

The selection of a model must, therefore, be based on other considerations, such as the simplicity of the Sinclair model, which would dramatically decrease computer processing time for large numbers of simulations. The Stewart model is

Table 5. Statistics derived from linear regressions and accuracy analysis relative to unfertilized fallow-wheat rotation ($n = 79$)

Actual mean yield (A) = 211 g m^{-2}

Parameters	EPIC	Century	CERES[‡]	Stewart	Sinclair
Predicted mean yield (P_t)	190	183		147	308
Mean difference (MD = $A-P_t$)	21	28		64	−97
Intercept (a)	148	245		72	124
Slope (b)	0.32*	−0.19		0.94*	0.28*
Correlation coefficient (r)	0.39	−0.17		0.75	0.41
Bias error (U^m)	0.05	0.06		0.62	0.46
Regression error (U^r)	0.40	0.53		0.00	0.31
Random error (U^e)	0.55	0.41		0.38	0.23

[‡] Rotation not simulated.
* Significant at $P = 0.05$.

Table 6. Statistics derived from linear regressions and accuracy analysis relative to fertilized fallow-wheat rotation ($n = 24$)

Actual mean yield (A) = 267 g m^{-2}

Parameters	EPIC	Century	CERES[‡]	Stewart[‡]	Sinclair
Predicted mean yield (P_t)	238	236			274
Mean difference (MD = $A-P_t$)	29	31			−7
Intercept (a)	174	309			82
Slope (b)	0.39*	−0.17			0.67*
Correlation coefficient (r)	0.71	−0.17			0.79
Bias error (U^m)	0.09	0.05			0.02
Regression error (U^r)	0.64	0.59			0.28
Random error (U^e)	0.27	0.36			0.70

[‡] Rotation not simulated.
* Significant at $P = 0.05$.

Table 7. Statistics derived from linear regressions and accuracy analysis relative to unfertilized (n = 79) and fertilized (n = 24) fallow-wheat-wheat rotation

Unfertilized actual mean yield (A) = 194 g m^{-2}
Fertilized actual mean yield (A) = 242 g m^{-2}

	Unfertilized		Fertilized	
Parameters	EPIC	Century	EPIC	Century
Predicted mean yield (P_t)	200	184	241	232
Mean difference (MD = $A-P_t$)	−6	10	1	10
Intercept (a)	113	214	159	244
Slope (b)	0.45*	−0.11	0.34*	−0.01**
Correlation coefficient (r)	0.36	−0.10	0.71	0.00
Bias error (U^m)	0.00	0.01	0.00	0.00
Regression error (U^r)	0.47	0.57	0.80	0.57
Random error (U^e)	0.53	0.42	0.20	0.43

* Significant at P = 0.05.

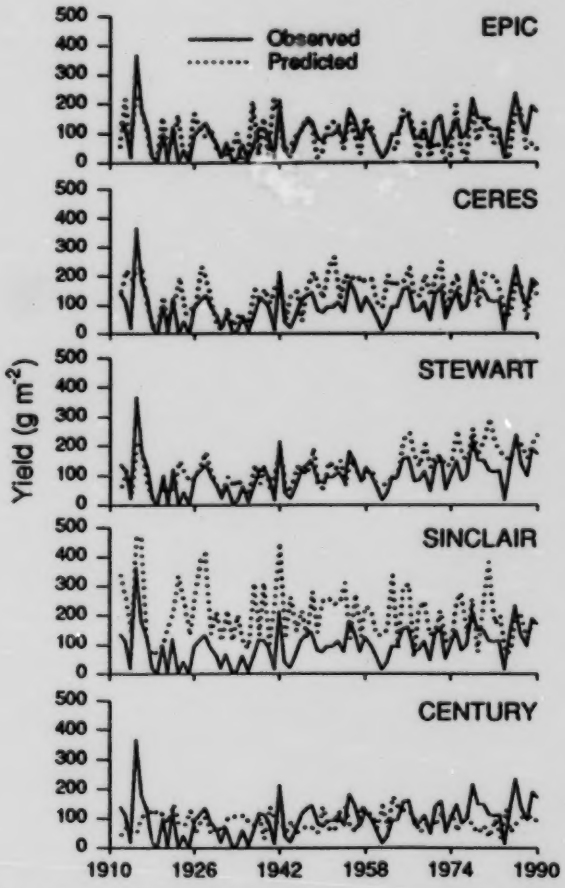

Fig. 1. Comparison between predicted yields by the EPIC, CERES, Stewart, Sinclair and Century models and unfertilized continuous wheat yields observed over 79 yr.

constrained by the time trend since there is no information on its future direction. The Stewart, EPIC and Century models have the advantage of multi-crop capability. Similarly, a disadvantage of CERES and Sinclair is that they are single crop models. The Stewart model was most accurate for predicting yields of unfertilized continuous wheat and fallow-wheat; Sinclair was best for the fertilized fallow-wheat rotation; and CERES was best for fertilized continuous wheat. Further tests of these models should include a sensitivity analysis and a comparison of predictions for the entire Prairie region.

While none of the models produced high correlation with the observed yield there was good agreement between mean yields by rotation and for dry years. In addition, EPIC and Stewart both had extremes that were comparable to the observed yields even though the slopes were less than unity. These results lead to the conclusion that EPIC in particular is capable of simulating yields that appear realistic even if they do not correlate particularly well with the historical time series from the 'ABC' rotation.

The EPIC model is versatile because it was developed to simulate different crops grown under different management practices and it takes into account the effects of soil erosion. Therefore, it has better potential for assessing climate change on agricultural production.

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Table 8. Monthly mean climate parameters recorded over 79 yr (a) and 12 drought yr (b)

Month	Solar radiation (MJ m^{-2})		Max. temperature (°C)		Min. temperature (°C)		Precipitation (mm)	
	a	b	a	b	a	b	a	b
1	5.0	4.8	−2.7	−1.9	−14.6	−13.3	19.1	17.7
2	8.0	8.0	−0.3	−0.2	−12.5	−12.0	18.3	11.3
3	13.0	12.0	4.4	4.4	−8.0	−6.8	24.7	30.3
4	18.0	18.3	12.2	12.2	−1.5	−1.4	31.7	34.5
5	22.0	22.4	17.8	18.0	3.8	4.1	47.9	48.2
6	24.0	24.5	21.8	22.5	8.1	8.5	70.5	51.1
7	24.0	24.1	25.7	26.8	10.4	10.6	41.6	29.1
8	20.0	20.5	24.8	25.8	9.3	9.7	41.4	30.2
9	15.0	14.9	19.1	18.6	4.7	4.7	41.8	43.4
10	10.0	9.7	13.7	13.3	0.0	0.4	21.5	34.4
11	6.0	5.9	5.1	5.1	−6.8	−6.2	19.2	23.0
12	4.0	4.4	−0.4	−1.0	−11.6	−11.3	18.7	19.5
Mean	14.0	14.1	11.7	11.9	−1.5	−1.1	33.0	31.0

Table 9. Statistics derived from linear regressions and accuracy analysis relative to unfertilized continuous wheat rotation for drought years (n = 12)

Actual mean yield (A) = 44 g m^{-2}

Parameters	EPIC	Century	CERES	Stewart	Sinclair
Predicted mean yield (P_i)	54	94	125	78	151
Mean difference (MD = $A-P_i$)	−10	−50	−81	−35	−107
Intercept (a)	37	86	4.4	37	38
Slope (b)	0.13	−0.45	0.31	0.08	0.54
Correlation coefficient (r)	0.20	−0.35	0.48	0.10	0.28
Bias error (U^m)	0.03	0.49	0.74	0.34	0.73
Regression error (U^r)	0.66	0.30	0.16	0.31	0.20
Random error (U^e)	0.31	0.21	0.10	0.35	0.07

Table 10. Statistics derived from linear regressions and accuracy analysis relative to unfertilized fallow-wheat rotation for drought years (n = 12)

Actual mean yield (A) = 173 g m^{-2}

Parameters	EPIC	Century	CERES[1]	Stewart	Sinclair
Predicted mean yield (P_i)	159	203		100	245
Mean difference (MD = $A-P$)	14	−30		73	−72
Intercept (a)	159	129		125	124
Slope (b)	0.08	0.21		0.47	0.28
Correlation coefficient (r)	0.20	0.33		0.39	0.51
Bias error (U^m)	0.02	0.17		0.73	0.52
Regression error (U^r)	0.82	0.51		0.05	0.33
Random error (U^e)	0.16	0.32		0.22	0.15

[1] Rotation not simulated.

Table 11. Statistics derived from linear regressions and accuracy analysis relative to unfertilized fallow-wheat-wheat rotation for drought years (n = 12)

Actual mean yield (A) = 146 g m^{-2}

Parameters	EPIC	Century	CERES[1]	Stewart[1]	Sinclair[1]
Predicted mean yield (P_i)	165	202			
Mean difference (MD = $A-P_i$)	−19	−56			
Intercept (a)	141	109			
Slope (b)	0.03	0.18			
Correlation coefficient (r)	0.00	0.28			
Bias error (U^m)	0.03	0.40			
Regression error (U^r)	0.83	0.39			
Random error (U^e)	0.14	0.21			

[1] Rotation not simulated.

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Sensitivity of four wheat simulation models to climate change

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Touré, A., Major, D. J. and Lindwall, C. W. 1995. **Sensitivity of four wheat simulation models to climate change.** Can. J. Plant Sci. 75: 69–74. Crop simulation models may be valuable in anticipating crop production under a changed climate. We compared four computer simulation models of wheat, crop estimation through resources and environment synthesis (CERES), erosion productivity impact calculator (EPIC), Stewart and Sinclair, for evaluating the impact of climate change on dryland spring wheat yield for continuous rotation in southern Alberta. To a varying extent, the four models showed decreases in dryland spring wheat yields due to high temperature and low precipitation. All the models except Stewart had similar sensitivity to low precipitation; however, they showed differences to high-moisture conditions. Within the range considered, the Sinclair model was the most sensitive to temperature, followed by CERES and Stewart. Only EPIC indicated optimum temperature and precipitation levels, while CERES had the most pronounced precipitation optimum. Although the CERES, Stewart and Sinclair models have different phenology submodels, they predicted similar phenological response to a doubled CO_2 climate scenario generated from the Canadian Climate Center General Circulation Model for Lethbridge, AB. Growing seasons shortened by 19 d were predicted using CERES and 18 d by using the Sinclair and Stewart models. The CERES, Stewart and Sinclair models were modified to include the effect of CO_2 on radiation-use-efficiency. With current atmospheric CO_2 concentration in the future climate scenario, the EPIC and Stewart models predicted significant (25%) and non-significant (3%) yield increases for dryland wheat and Sinclair and CERES predicted yield losses. Higher CO_2 levels may compensate for the effect of global warming; doubling CO_2 from present levels in a warmer climate scenario resulted in yield increase predictions at different amplitudes using EPIC, Stewart and CERES and a slight yield decrease with Sinclair.

Key words: Sensitivity, climate change, dryland spring wheat

Touré, A., Major, D. J. et Lindwall, C. W. 1995. **Sensibilité aux changements climatiques de quatre modèles en simulation de culture du blé.** Can. J. Plant Sci. 75: 69–74. Les modèles en simulation peuvent être des outils précieux pour prévoir la productivité des cultures en fonction des modifications du climat. Nous avons comparé quatre modèles en simulation (informatisés) de culture du blé, soit CERES, EPIC, Stewart et Sinclair pour évaluer les conséquences des changements climatiques sur le rendement du blé de printemps cultivé en continu en conditions non irriguées dans le sud de l'Alberta. Dans une plus ou moins grande mesure, les quatre modèles prédisaient des baisses de rendement du blé en régime de températures élevées et de précipitations faibles. Tous les modèles, sauf Stewart manifestaient le même degré de sensibilité aux faibles précipitations, mais des différences apparaissaient en régimes de précipitations abondantes. Dans l'écart considéré, c'est le modèle Sinclair qui était le plus sensible aux changements de température, suivi de CERES et de Stewart. Seul EPIC faisait voir les niveaux optimaux de température et de précipitations. CERES produisait l'optimum de précipitations le plus prononcé. Bien que CERES, Stewart et Sinclair comportaient des sous-modèles différents selon le développement phénologique, ils prédisaient une réponse phénologique au scénario de doublement de la concentration de CO_2 de l'atmosphère, généré pour la région de Lethbridge en Alberta à partir du modèle général de circulation du Centre climatique canadien. Un raccourcissement de 19 jours de la saison de végétation était prédit par CERES et de 18 jours par les modèles Sinclair et Stewart. Ces trois modèles ont été modifiés de façon à inclure l'effet du CO_2 sur l'efficacité du rayonnement photosyntétique. Aux concentrations atmosphériques courantes de CO_2, dans le scénario climatique envisagé, EPIC et Stewart prédisaient des accroissements significatifs (25%) et non significatifs (3%) du rendement du blé, cependant que Sinclair et CERES prédisaient des chutes de rendement. L'accroissement des concentrations de CO_2 peut compenser l'effet du réchauffement planétaire; le doublement des concentrations de CO_2 par rapport aux niveaux actuels dans un scénario de réchauffement du climat se traduisait par des prédictions d'accroissement du rendement de divers ordres de grandeur selon EPIC, Stewart et CERES et de légères baisses de rendement selon Sinclair.

Mots clés: Sensibilité, changement climatique, blé de printemps en culture sèche

Global climate change as a result of increasing atmospheric concentration of greenhouse gases is predicted to raise mean global air temperature 1.5–4°C by 2050, with the greater increases at higher latitudes (Gates et al. 1984; Hansen et al. 1984). Prairie crop production may be severely affected by changes in average temperature and precipitation as well as by weather variability (Mearns et al. 1992). The direct effects of rising CO_2 concentration is expected to promote increased photosynthesis, water use efficiency and crop productivity (Wolfe and Erickson 1993). Prediction of the

Abbreviations: CERES, crop estimation through resources and environment synthesis; EPIC, erosion productivity impact calculator; RUE, radiation-use-efficiency

impact of climate change on agricultural production on the prairies may allow appropriate steps to be taken to mitigate negative effects or maximize positive effects.

Simulation models have been used to integrate the many factors affecting crop production and predict the effect of climate change. Several models have been used to examine possible climate effects on the prairies (Bootsma et al. 1984; Williams et al. 1988; Brklacich et al. 1991). However, predictions from models depend on the climate–crop–soil assumptions used in creating the model. Sensitivity analysis of crop models with common climatic datasets can help in understanding how the models perform under global change conditions, which may help in the selection of model for climate change studies.

The EPIC (Williams et al. 1990), the CERES (Ritchie and Otter 1985), the Stewart (Stewart and Dwyer 1990) and the Sinclair (Amir and Sinclair 1991) are prominent mechanistic wheat models described by Touré et al. (1995). All four models use daily weather parameters to simulate crop growth based on similar approaches but different algorithms. For all of them, air temperature is considered to control phenological development based on daily heat unit accumulation and photoperiod. Solar radiation is assumed to affect biomass accumulation and evapotranspiration in the EPIC, CERES and Sinclair models. The Stewart model approximates solar radiation using daily temperature range to calculate dry matter accumulation as influenced by water stress. The models include precipitation influences on the amount of water available in the soil–crop system and water loss through evapotranspiration and drainage. The CERES and Sinclair models allow users to specify soil moisture conditions at seeding date while the EPIC and Stewart models calculate it from field capacity, wilting point and the amount of precipitation. Each of the models uses different algorithms to compute potential evapotranspiration from temperature, incoming solar radiation (EPIC, CERES and Sinclair) or temperature and solar radiation at the top of the atmosphere (Stewart).

The objective of this study was to compare the response of dryland spring wheat yield to climate parameters according to the above described wheat simulation models. This was done by (1) conducting a sensitivity analysis of crop models to different climate regimes and (2) evaluating yield prediction of the models under a doubled CO_2 climate scenario.

MATERIALS AND METHODS

Models' Input and Climate Parameters

The input parameters describing the crop and soil characteristics and used to validate the four models in a companion paper (Touré et al. 1995) were maintained for this study. These parameters produced significant correlations between estimated and observed long-term dryland spring wheat yields under different rotations and amounts of fertilizer. A detailed description of these inputs is given by Touré et al. (1995).

The EPIC, CERES, Stewart and Sinclair models were run using a range of artificial climate parameters and a scenario derived from the Canadian Climate Center General Circulation Model (GCM) (McFarlane et al. 1992). A range of climate parameters, assumed constant over the growing period, were input into the models to evaluate their effect on estimated spring wheat yield for an unfertilized continuous rotation. Maximum daily mean temperatures from 15°C to 30°C in 2.5°C steps were used with minimum daily mean temperature set to 5, 10 and 15°C lower than maximum temperature and precipitation from 5 to 25 mm in 2.5 mm steps, assuming 5 d between each rainfall. To limit the complexity of the test, global incoming solar radiation at the surface was not altered as initial analysis (historical solar radiation changed by −2, 0, +2 MJ m^{-2}) indicated little or no change for any of the models.

A climate scenario derived from the GCM output data for Lethbridge, Alberta (112°50′W; 49°42′N), was used to evaluate phenological (maturity date, except EPIC) and growth (yield) response predictions of the models. Phenological dates (sowing and maturity dates) are input parameters in the EPIC model, whereas the CERES and Sinclair models compute the maturity date from an input sowing date using their phenological submodels. For these models, average observed seeding date (2 May) from 30 yr (1961–1990) was assumed under the climate scenario. The Observed mean maturity date and that predicted under the climate scenario using the CERES model were used as inputs in the EPIC model. The Stewart model estimated seeding dates by calculating daily values of soil moisture content for 40 d after 1 May and days when soil moisture of the soil surface was below the field capacity were counted as seeding dates. The GCM data consisted of monthly climatic variables, maximum and minimum air temperatures and precipitation under present (330 ppm) and doubled (660 ppm) CO_2 levels. Mean monthly differences in maximum and minimum temperatures predicted in the GCM were added to historical daily records, for Lethbridge, for the period from 1961 to 1990, to generate daily minimum and maximum temperatures for the scenario. For example, the difference in mean temperatures for January estimated from the GCM was added to the observed minimum and maximum temperature values for each January day in the historical data. For precipitation,

Table 1. Mean monthly maximum and minimum temperatures and total monthly precipitation from the observed (1961–1990) record and the GCM derived climate scenario

	Historic data			GCM derived climate scenario		
Month	Max. temp. (°C)	Min. temp. (°C)	Precip. (mm)	Max. temp. (°C)	Min. temp. (°C)	Precip. (mm)
1	−2.6	−14.2	20.4	3.1	−6.3	35.2
2	1.0	−11.1	12.8	6.3	−4.1	13.9
3	5.3	−7.0	25.2	9.5	−0.2	27.8
4	12.2	−1.0	32.2	14.8	5.1	47.4
5	17.8	4.3	48.2	26.1	11.1	68.0
6	22.3	8.8	63.7	25.8	13.1	65.2
7	25.5	10.5	39.5	28.1	14.2	46.2
8	24.9	9.8	44.5	28.3	14.1	37.6
9	19.2	4.9	41.2	22.2	8.6	60.1
10	14.1	0.5	14.8	16.9	2.4	16.8
11	4.4	−6.9	16.1	6.8	−5.4	22.3
12	−1.1	−12.3	19.6	3.3	−2.6	25.7
Mean	11.9	−1.2	31.5	15.9	4.2	38.8

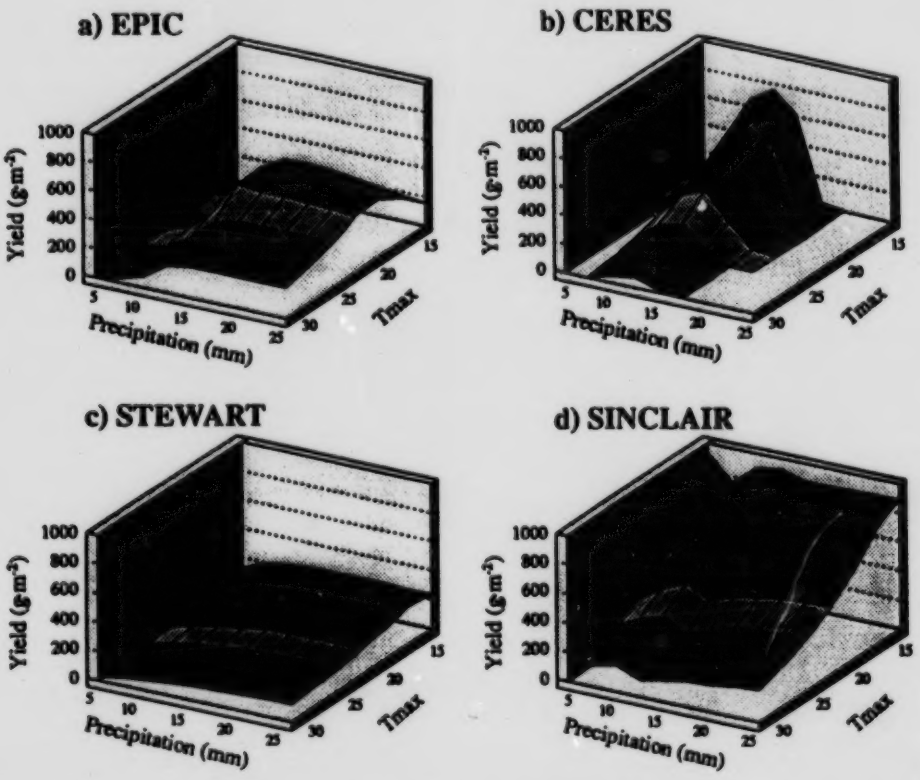

Fig. 1. Changes in dryland spring wheat yield due to changes in maximum temperature and precipitation, according to the (a) EPIC (b) CERES (c) Stewart and (d) Sinclair models.

observed daily values were multiplied by the ratio of the levels predicted with doubled CO_2 to those at present day CO_2 concentrations. Year-to-year variability in the Lethbridge weather data was maintained using this method since there is considerable uncertainty regarding the extent to which climate variability will change (Mearns et al. 1992). The GCM predicted an annual increase in maximum and minimum temperatures and total precipitation of 4.0°C, 5.4°C and 23.2%, respectively, with the increases higher in winter and spring (Table 1). Dryland spring wheat yields predicted by the models using historical weather data for the period 1961–1990 ($1 \times CO_2$) were used as a reference for comparing yield in a future scenario ($2 \times CO_2$). When the ratio of $2 \times CO_2$ to $1 \times CO_2$ simulated yields was greater than one, one, and less than one, it indicated an increase, no change, and a loss of yield, respectively.

Modification of the Models to Include Direct CO_2 Effect

The GCM climate scenario was used with 330 and 660 ppm CO_2 in all four models. The EPIC model already included a CO_2 concentration variable (Easterling et al. 1992; Stockle et al. 1992), but the other three models have no direct CO_2 parameter. The CERES, Sinclair and Stewart models were modified to include the effect of CO_2 on radiation-use-efficiency (RUE) which represents the ratio of the amount of crop dry matter produced per unit of intercepted photosynthetically active radiation. The following equation developed for wheat by Easterling et al. (1992) and Stockle et al. (1992) was used:

$$RUE = 100 \times CO_2/(CO_2 + b_1\exp(-b_2CO_2)) \quad (1)$$

The values of b_1 ($b_1 = 7784$) and b_2 ($b_2 = -0.00107$) used in this study corresponded to calculated values for RUE of wheat (Stockle et al. 1992). Other physiological processes believed to be affected by CO_2 concentration, such as leaf resistance and transpiration of crops, were not addressed. Increasing CO_2 concentration from 330 to 660 ppm resulted in an apparent 38% increase in RUE.

RESULTS AND DISCUSSION

Effect of Increased Temperature and Precipitation on Wheat Yield

Precipitation and air temperature effects on predicted dryland spring wheat yield varied markedly among the models (Fig. 1 and Tables 2 and 3). Minimum temperature effects on yield are not presented since the sensitivity patterns were similar to those generated using maximum temperature.

Table 2. Slopes of change in unfertilized dryland spring wheat yields due to changes in precipitation (g m^{-2} mm^{-1}), according to the EPIC, CERES, Stewart and Sinclair models

	Temperature (°C)							
	15	17.5	20.0	22.5	25.0	27.5	30.0	Mean
EPIC								
5 - 15 mm	21.4	36.9	44.1	55.4	20.4	20.5	10.2	29.8
15 - 25 mm	−7.2	−9.0	−6.5	−3.6	−0.72	−0.22	0.22	−3.9
CERES								
5 - 12.5 mm	83.9	70.9	53.7	36.7	31.2	18.5	9.1	43.4
12.5 - 25 mm	−76.1	−64.7	−49.4	−36.3	−23.4	−18.5	−9.1	−39.6
Stewart								
5 - 25 mm	10.8	8.8	13.7	12.7	9.8	7.8	6.7	10.0
Sinclair								
5 - 10 mm	57.6	38.1	44.3	36.7	27.6	22.5	18.4	35.0
12.5 - 25 mm	2.1	3.3	5.8	6.4	9.1	9.1	7.5	6.2

Table 3. Slopes of change in unfertilized dryland spring wheat yields due to changes in temperature (g m^{-2} $°C^{-1}$), according to the EPIC, CERES, Stewart and Sinclair models

	Precipitation (mm 5 d^{-1})									
	5.0	7.5	10.0	12.5	15.0	17.5	20.0	22.5	25.0	Mean
EPIC										
15 - 20°C	1.9	9.5	18.5	41.6	45.8	47.8	48.7	48.6	47.2	34.4
20 - 30°C	−1.6	−6.5	−21.3	−25.5	−25.5	−25.2	−23.8	−21.5	−18.8	−18.8
CERES										
15 - 30°C	−13.2	−13.7	−40.1	−46.2	−39.4	−3.8	−1.6	—[1]	—[1]	−22.5
Stewart										
15 - 30°C	−7.0	−9.6	−10.2	−10.2	−11.4	−11.2	−11.2	−10.8	−10.7	−10.2
Sinclair										
15 - 30°C	−56.0	−40.7	−47.5	−53.5	−48.2	−46.9	−46.3	−45.5	−44.6	−47.7

[1]Crop damaged by excess water.

All the models showed an increase in yield when precipitation was increased (Fig. 1 and Table 2). Over the entire range of precipitation, the Stewart (Fig. 1c) and Sinclair (Fig. 1d) models showed an increase in yield, with Sinclair showing higher sensitivity (significantly different at $P > 0.1$ from the Stewart predictions) at low precipitations (5–10 mm). Predicted yields increased with precipitation to an optimum of 15 mm every 5 d using EPIC (Fig. 1a) and 12.5 mm every 5 d using CERES (Fig. 1b), decreasing at higher precipitation. The CERES model showed decreasing yield (−39.6 g m^{-2}/mm) beyond the optimum precipitation whereas EPIC showed small yield decreases (−3.9 g m^{-2} mm^{-1}), indicating greater sensitivity of the CERES model to excess water. Average slopes obtained from the EPIC (5–15 mm), Sinclair (5–10 mm) and CERES (5–12.5 mm) models were not significantly different, suggesting these models have similar sensitivity to low precipitation.

High temperatures have been reported to accelerate crop development, reduce leaf area duration, decrease seasonal interception of photosynthetically active solar radiation, and reduce yields (Amir and Sinclair 1991; Brklacich et al. 1991; Stockle et al. 1992). All the models, except EPIC (15–20°C), predicted a decrease in yield when temperature increased (Fig. 1 and Table 3). Within the range considered, the Sinclair model was most sensitive to temperature (−47.7 g m^{-2} $°C^{-1}$; significantly different from the CERES result at $P > 0.1$), followed by CERES (−22.5 g m^{-2} $°C^{-1}$), EPIC (−18.8 g m^{-2} $°C^{-1}$) and Stewart (−10.2 g m^{-2} $°C^{-1}$). The EPIC was the only model which showed an optimum temperature; yield increased with temperature up to an optimum 20°C and decreased thereafter, probably a more realistic scenario.

Impact of GCM Climate Scenario on Wheat Maturity Date

The EPIC was not considered in this analysis as sowing and maturity dates are input parameters. The Stewart model predicted later mean seeding dates, 10 and 11 May, for historic data and the scenario generated from the GCM and it suggested no change in the average seeding date under the scenario considered (Table 4).

Accelerated crop development as temperature increases was reflected in predictions of all the models when run using the climate scenario derived from the GCM. The models predicted maturity dates earlier by 19 d for CERES and 18 d for Sinclair and Stewart models due to temperatures 4°C

Table 4. Average spring wheat maturity date (Julian date) predicted by the CERES, Stewart and Sinclair models as affected by the GCM derived climate scenario

Climate scenario	CERES		Stewart		Sinclair	
	Sowing	Maturity	Sowing	Maturity	Sowing	Maturity
Current climate	122[z]	227	130[y]	223	122[z]	227
GCM	122[z]	208	131[y]	205	122[z]	209
difference		−19		−18		−18

[z],[y] Observed and estimated mean sowing dates (30 yr average), respectively.

Table 5. Ratio of future to current estimated dryland spring wheat yield using the GCM derived climate scenario, according to EPIC, Sinclair, CERES and Stewart models with atmospheric CO_2 concentration fixed at 330 and 660 ppm

CO_2 (ppm)	EPIC	CERES	Stewart	Sinclair
330	1.25	0.64	1.03	0.85
660	1.28	1.15	1.37	0.99

higher than the mean for 1961–1990 (Table 4). Maturity date changes were similar for all the models, suggesting use of similar phenological response functions. Under the current climate, the CERES and Sinclair models indicated an average maturity date of 15 August and the Stewart prediction was 4 d earlier (11 August). A similar observation for spring wheat was made by Brklacich et al. (1991) for Lethbridge, using the CERES–wheat model. They found that a 4°C increase in temperature hastened spring wheat maturity by 18 d. Butterfield and Morison (1992) predicted higher winter wheat growing season reductions, 30 and 49 d at Edinburgh, Scotland, due to atmospheric warming of 2°C and 4°C.

Estimated Direct and Indirect Effect on Yield of Doubled CO_2 Level

The effects of the doubled CO_2 climate scenario, with and without the direct effects of doubling atmospheric concentration of CO_2, varied with the models (Table 5). Assuming no direct effect of CO_2 (330 ppm), CERES and Sinclair models-predicted dryland wheat yield reductions of 36 and 15%, respectively, for the GCM derived climate change scenario, probably due to their high sensitivity to temperature, while EPIC and Stewart models predicted gains of 25 and 3%. These predictions were consistent with the models' sensitivity to other climate parameters (Fig. 1).

The direct effect of doubling atmospheric CO_2 (660 ppm) in the models ameliorated the predicted impact of climate on yield. At 660 ppm, the models showed an increase in yield relative to those obtained at 300 ppm CO_2 (Table 5). The relative yield increase between 330 and 660 ppm CO_2 was less with EPIC (3%) than Sinclair (14%), Stewart (34%) and CERES (47%). CERES' higher predicted yield may be due to its wheat growth calculation, in which biomass accumulation and leaf area index are related processes, so a 38% increase in RUE due to doubling atmospheric CO_2 generates a greater increase in biomass, leaf area index and yield than in other models in which RUE only impacts biomass accumulation. The EPIC and modified Stewart and CERES models predicted 28, 37 and 15% gains in yield, respectively, and the modified Sinclair model predicted a slight loss (1%) in yield as a result of combined direct and indirect effects of doubling CO_2 concentration.

In controlled environments where water, nutrients, temperature, and pest pressure were optimum, elevated CO_2 increased yields by 20–80% depending on crop type and condition (Kimball 1983; Cure and Acock 1986; Hendrey 1992). Cure and Acock (1986) reported that low nutrient concentrations limited the responses of most crops to CO_2. Our results for unfertilized dryland conditions are, in part, a function of the way CO_2 affects simulated physiological processes in the four models. The effect of CO_2 only on RUE is considered in the Sinclair, CERES and Stewart models. The EPIC model also considers the effect of daily vapour pressure deficit on RUE and it indicated significant stress on spring wheat growth because of limited water and nutrients, which may explain the small effect (3% increase in yields) predicted with increased CO_2.

Similar results were obtained by Brklacich et al. (1991) using the CERES model and three general circulation models to predict the impact of future climate scenarios on yield. They predicted an 18% yield improvement for Lethbridge, using a scenario (20% and 6°C increase in precipitation and temperature, respectively) derived from the United Kingdom Meteorological Office GCM with doubled CO_2.

There are several sources of uncertainty in any future scenario prediction. The four crop models underestimate year-to-year variability in yield (Touré et al. 1995) which may be significant if future climate exhibits greater variability. In addition, the models have been developed under current climatic conditions using empirical relationships and parameters derived from controlled experiments and may not be valid for a changed climate. GCMs are presently not considered to be accurate for local assessments (Mearns et al. 1992; Cess et al. 1993). Although they have limitations in how well they simulate current climate, the greatest uncertainty is in their ability to predict future climate change, especially as it pertains to precipitation (Rosenzweig and Parry 1993). Nevertheless, the selection of a model such as EPIC for yield assessment under altered climate conditions appears reasonable.

CONCLUSIONS

The four models presented in this study show different sensitivities to temperature and precipitation because of differences in their simulation of crop growth. To a varying extent, all the models showed decreases in dryland spring wheat yields due to high temperature and low precipitation. All the models, except the Stewart, have similar sensitivity to low precipitation; however, differences were evident under

high-moisture regimes. Within the range considered, the Sinclair model was the most sensitive to temperature, followed by CERES and Stewart. Only EPIC indicated an optimum temperature and precipitation, while CERES had the most pronounced precipitation optimum. The differences in sensitivity of the models suggest that the predicted impact of climate on dryland spring wheat depends on the model used.

The CERES, Sinclair and Stewart models have similar phenological responses to a future climate scenario, even though they have different phenological submodels. The models predicted that a warmer (4°C increase) climate in southern Alberta would shorten the wheat-growing season by 19 (CERES) or 18 (Stewart and Sinclair) days, using current seeding dates.

The EPIC and Stewart models predicted dryland spring wheat yield benefits of 25 and 3%, while CERES and Sinclair predicted losses of 36 and 15%, compared with present yields, due to the warmer climate scenario at an atmospheric CO_2 concentration of 330 ppm. Direct effects of increased CO_2 may mitigate the effect of climate warming on yield. With an atmospheric CO_2 concentration of 660 ppm, Stewart, EPIC and CERES models predicted yield gains of 37, 28 and 15%, respectively, while the Sinclair model predicted a loss of 1%.

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Chapter IV. AGROCLIMATIC INDICES

I. Introduction

There exist several simple indices related to plant growth and development that depend on weather data, including frost free days and growing degree days (GDD). The GDD concept is based on the principle that plant growth is a function of temperature so that if the temperatures above a base temperature are accumulated over a time period, the GDD accumulation will be related to plant developement. Plant development describes the progression toward maturity. Plant growth is defined as the increase in volume or height and often refers to increase in mass. Growth cannot be related to GDD because it is a more complex function, usually involving plant water relations and the interception of solar radiation.

By dividing crops into temperate and tropical, the GDD can be grouped according to base temperature. The temperate crops have a lower initial starting temperature and a lower optimum than tropical crops. Temperate crops include the small grains, wheat, barley, oats and rye, many of the forages such as alfalfa, the clovers, bromegrass, orchard and timothy, and broadleaf annual crops such as canola, peas, and lentils. Tropical grasses are the C_4 species of corn, sorghum and sugar cane, and broadleaf species such as field bean and soybean. The base temperature for the temperate crops are usually 0 to 5°C and 8 or 10°C for the tropical species.

In reality, the temperature response function has a lag phase where some development occurs at low temperatures but the rate of increase is relatively slow as temperature increases. At approximately the base temperature, development increases at an almost linear rate until the optimum is reached. On either side of the optimum there is some curvature in the response and then the temperature drops very rapidly toward a lethal temperature. This decline at high temperatures is much more rapid than the increase.

The most common GDD formula simply adds temperatures above the base with no consideration of the optimum, assuming that detrimental temperatures seldom occur. Thus it assumes a linear response with an X-intercept at the base temperature, and a slope of unity.

The thermal time formulae also generally utilize the daily maximum and minimum temperatures although there are some hourly accumulations. The additional computing time to generate hourly estimates has seldom been shown to be justified. Another assumption in GDD work is that the temperature recorded at the nearest weather station is applicable to the temperature of the crop. In fact, this is a poor assumption since early in the season grass species growing point

temperature would be more accurately accounted for by 5cm soil temperatures as the growing point is below the soil until approximately the onset of rapid growth. In addition, 5cm soil temperature has a notoriously poor relationship with air temperature. After the growing point is above the soil the air temperature should be more closely related to that of the crop. For a well watered, well developed canopy this temperature is a function of both air temperature and vapour pressure and can be as much as 8°C less than air temperature. For a sparse canopy with bare soil visible, or a water stressed canopy, the growing point temperature can be equal to or greater than air temperature.

In spite of these difficulties, thermal time estimates have a generally good relationship with development and are used to guage the capacity of a geographic region to grow certain crops and for identifying the appropriate maturity class of crops for certain geographic regions.

There are many incarnations of thermal time. Besides the GDD there is the popular Canadian corn heat unit (CHU) which has a curvilinear response to maximum temperature. The most popular GDD's have bases of 0 and 10°C but 5 and 8°C are also used. Also of value is the estimate of frost free days (FFD), for the purposes of this report, the time from the last day of spring when the minimum temperature of -2°C is recorded until the same temperature is recorded in the fall. The -2°C temperature has been recognized as an appropriate temperature at which frost damage actually occurs. Other interesting thermal events are the average date when temperature reaches 11°C, which as been found to be associated with the onset of regrowth (RGRW) of temperate grasses and the date when the average temperature decreases to 11°C which some have found to correspond to the critical fall harvest date of alfalfa. The critical fall harvest date refers to a four week period when the alfalfa plant diverts photosynthate to the roots to provide nutrients for surviving the winter. Cutting the crop during this period will require utilization of root reserves for regrowth and subsequent loss of winter hardiness.

Another measure of thermal time, contrary to plant growth, is heating degree days (HDD). This is accumulation of thermal time below an upper base, generally 18°C, and is related to consumption of energy for heating during the winter.

II. Methods

Series of shell scripts were written to access the 166 weather grid points considered to contain acceptable quality data. These points contained complete data for the 30 year period and fortunately they fall within the agricultural region of Alberta.

The series of shell scripts consisted of a VMS command program (Appendix E-IV.1) which

called a Fortran program (Appendix E-IV.2) to calculate the agroclimatic index of interest for each of the selected grid points. The Fortran program produced an output for each of the thirty years of data and a standard deviation was calculated. The grid points called by the command file are listed in Appendix E-IV.3.

The command program was run for the historical (SN6) and the $2xCO_2$ (SN5) scenarios. The SN5 scenario contained the GCM output for temperature and since the agroclimatic indices in this section were all controlled by temperature, it was sufficient to run them only for SN5 to compare with SN6. The agroclimatic indices included corn heat units (CHU), growing degree days (GDD_i) where i=base temperatures of 0, 5, 8 or 10°C), heating degree days with a base of 18°C (HDD_{18}), frost free days (FFD) and regrowth of perennials (Regrow). Frost free days were determined as the number of days between the last -2°C temperature and the first -2°C temperature. The value of -2°C was chosen because most frost damage does not occur until the temperature reaches at least -2°C. The regrowth of perennials was taken as the date when the ten-day average air temperature rose to 11°C, which was found to coincide with the date when winter wheat began the rapid growth phase (Major et al., 1988).

The latitude and longitude of each of the grid points was converted to UTM coordinates in the GRASS (Geographic Resource Analysis Support System) GIS and the file was reformated for the GRASS program *s.in.ascii* (Appendix A-IV.3). A SAS summary program was written to determine correlation coefficients and to determine the mean and range of the data (Appendix A-IV.4). These results were used in another GRASS program (s_in_ascii.sas) to create classes for each of the agroclimatic indices (Appendix A-IV.5). Unix shell scripts were written to copy the VMS data files to the unix operating system and to generate all of the maps (Appendix A-IV.6). Category files were created and another SAS file (*report.sas*) was written to regenerate actual values of the agroclimatic indices for each regional municipality or crop reporting district and to reformat the data (Appendix A-IV.7).

The raw values for the agroclimatic indices for each grid point are listed in Appendix B-IV.8. Additional reports were generated to determine the concordance of the agroclimatic index with the Regional Municipalities of Alberta (Appendix C-IV.9) and for each of the Crop Reporting Districts of Alberta (Table IV.2), acquired from the Alberta Wheat Pool.

III. Results

The thermal time indices were all highly correlated with each other with coefficients of determination between 0.41 and 0.99. Thermal time typically decreases as elevation and latitude

increase. Consequently, the Medicine Hat area is the warmest with some cooling to the south east due to the Cypress Hills. Otherwise the accumulation of heat units decreases rapidly to the west of Medicine Hat and somewhat more slowly toward the north.

The statistics for each of the indices by crop reporting districts are presented in Table 2. It is apparent that the impact of climate change has a very large effect on heat unit accumulation. The highest number of CHU in the historical scenario was approximately 2600 but this increased to 3765 which is equivalent to south western Ontario. If the climate change scenario is accepted, this suggests dramatic shifts in the crops that will be grown and in the potential suite of crops that can be grown.

Similarly, climate change has a dramatic impact on the number of frost free days. These results show that an average annual temperature increase of 4 °C results in an extension of the growing season of about 38 days, changing from 132 FFD to 170 FFD. The estimated date for winter wheat regrowth in the Medicine Hat area (grid point BE51) is currently April 19 but with climate change this will be advanced to March 9. The critical fall harvest date for alfalfa for the same grid point changes from September 24 to October 8. Similar dates for the Fort McMurray area are that FFD will increase from 129 to 158, winter wheat regrowth will advance from May 20 to May 7 and critical fall harvest dates will change from September 7 to September 29. The CHU in Fort McMurray will increase from 2031 to 2688.

Heating degree days provide an estimate of the severity of the winter and are related to the consumption of fossil fuels for heating. Climate change will reduce the Medicine Hat HDD from 5300 to 3800 C and for the Fort McMurray area (grid point DD39) from 6700 to 5500, a reduction of 2200 C. The actual warming will be greater in Fort McMurray.

IV. Discussion

Climate change will have a profound impact on the thermal regime of Alberta. The capacity for growing crops that now exists in Medicine Hat will be relocated north to Fort McMurray and Medicine Hat will have a thermal capacity for crop production equivalent to south western Ontario, northern California or Nebraska. This will be evident in seeding dates that are about 3 weeks earlier than the current dates, a frost free season that is about 40 days longer, earlier regrowth of perennials and winter wheat in the spring and less likelihood of winter kill of winter annual crops.

The impact of these changes will likely see a shift from spring to winter wheat. Most areas in which winter wheat can survive without damage tend to grow winter wheat rather than spring wheat. This is usually because the crop takes better advantage of stored winter soil moisture and

can avoid the deleterious effects of high summer temperatures.

Another important shift is likely to be a trend toward less area seeded to cool season crops such as the small grains and more area devoted to warm season crops such as corn. There will likely be fewer areas which can achieve high yield of canola and more areas which could grow soybeans. Research should be conducted to develop high-quality winter canola cultivars.

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Table IV-1: Correlation coefficients among agroclimatic indices for 166 weather grid points in Alberta.

	CHU	GDD0	GDD5	GDD8	GDD10.	HDD18	FFD	REGROW	ENGROW
CHU	1.00	0.96	0.99	0.99	0.99	-0.84	0.94	-0.81	0.88
GDD0	0.96	1.00	0.98	0.98	0.98	-0.91	0.95	-0.87	0.81
GDD5	0.99	0.98	1.00	0.99	0.99	-0.89	0.93	-0.87	0.83
GDD8	0.99	0.98	0.99	1.00	0.99	-0.89	0.93	-0.87	0.83
GDD10	0.99	0.98	0.99	0.99	1.00	-0.89	0.93	-0.87	0.83
HDD18	-0.84	-0.91	-0.89	-0.89	-0.89	1.00	-0.85	0.93	-0.64
FFD	0.92	0.95	0.93	0.93	0.93	-0.85	1.00	-0.80	0.84
REGROW	-0.81	-0.87	-0.87	-0.87	-0.87	0.93	-0.80	1.00	-0.60
ENGROW	0.88	0.81	0.83	0.83	0.83	-0.64	0.84	-0.60	1.00

Table IV-2a: Average corn heat units (CHU), growing degree days with a base of 0°C (GDD_0) and growing degree days with a base of 5°C (GDD_5) averaged for the 16 crop reporting districts in Alberta for climate at the current atmospheric CO_2 level (1x) and for an atmospheric CO_2 concentration two times the current level (2x) .

	Crop Reporting District	CHU		GDD_0		GDD_5	
		1x	2x	1x	2x	1x	2x
1	MedicineHat/Foremost	2604	3765	2288	3839	2302	3459
2	Brooks/Lethbridge	2540	3707	2262	3781	2281	3397
3	Claresholm/Cardson	2113	3262	1939	3429	1962	3008
4	Hanna/Empress	2383	3377	2015	3468	2025	3079
5	Drumheller/Vulcan	2310	3367	2022	3460	2036	3066
6	Calgary/Olds	1837	2868	1682	3051	1707	2649
7	Stettler/Wainwright	2233	3248	1887	3273	1897	2906
8	RedDeer	1917	2922	1708	3021	1725	2661
9	RockyMountain-Region	1375	2290	1324	2605	1352	2182
10	Camrose/Vermilion	2143	3179	1813	3184	1823	2815
11	Edmonton	2066	3083	1775	3124	1786	2753
12	LacLaBiche/StPaul	1938	2714	1645	2826	1656	2414
13	Barrhead/Athabasca	1896	2889	1637	2942	1647	2586
14	Edmonton-West	1563	2485	1457	2693	1474	2310
15	NorthPeace	1848	2581	1595	2705	1607	2298
16	SouthPeace	1820	2727	1628	2842	1640	2447

Table IV-2b: Average growing degree days with a base of 8°C (GDD_8), growing degree days with a base of 10°C (GDD_{10}) and heating degree days below 18°C (HDD_{18}) averaged for the 16 crop reporting districts in Alberta for climate at the current atmospheric CO_2 level (1x) and for an atmospheric CO_2 concentration two times the current level (2x).

	Crop Reporting District	GDD_8		GDD_{10}		HDD_{18}	
		1x	2x	1x	2x	1x	2x
1	MedicineHat/Foremost	2311	3467	2316	3472	5305	3791
2	Brooks/Lethbridge	2292	3406	2300	3412	5252	3754
3	Claresholm/Cardson	1976	3017	1985	3024	5272	3783
4	Hanna/Empress	2031	3085	2035	3088	5901	4428
5	Drumheller/Vulcan	2045	3073	2050	3077	5627	4178
6	Calgary/Olds	1723	2658	1733	2664	5735	4313
7	Stettler/Wainwright	1903	2912	1907	2915	6012	4582
8	RedDeer	1736	2668	1743	2673	5907	4554
9	RockyMountain-Region	1369	2193	1380	2199	6061	4707
10	Camrose/Vermilion	1829	2820	1833	2823	6145	4716
11	Edmonton	1792	2759	1797	2763	5927	4594
12	LacLaBiche/StPaul	1662	2419	1667	2422	6758	5480
13	Barrhead/Athabasca	1654	2592	1658	2596	6254	4937
14	Edmonton-West	1484	2319	1491	2326	6067	4831
15	NorthPeace	1614	2304	1619	2308	6928	5712
16	SouthPeace	1647	2453	1651	2457	6307	5063

Table IV-2c: Frost free days (FFD) and winter wheat spring regrowth (RGRW) averaged for the 16 crop reporting districts in Alberta for climate at the current atmospheric CO_2 level (1x) and for an atmospheric CO_2 concentration two times the current level (2x) .

	Crop Reporting District	FFD		RGRW	
		1x	2x	1x	2x
1	MedicineHat/Foremost	146	184	Apr 21	Mar 10
2	Brooks/Lethbridge	147	183	Apr 15	Mar 6
3	Claresholm/Cardson	135	177	Apr 17	Mar 8
4	Hanna/Empress	135	173	May 12	Mar 29
5	Drumheller/Vulcan	140	177	Apr 28	Mar 16
6	Calgary/Olds	124	167	Apr 29	Mar 21
7	Stettler/Wainwright	137	177	May 14	Mar 24
8	RedDeer	133	172	May 5	Mar 21
9	RockyMountain-Region	110	156	May 12	Apr 6
10	Camrose/Vermilion	134	177	May 16	Mar 27
11	Edmonton	140	177	May 14	Mar 24
12	LacLaBiche/StPaul	128	160	May 22	May 1
13	Barrhead/Athabasca	133	172	May 19	Apr 6
14	Edmonton-West	126	163	May 14	Apr 3
15	NorthPeace	129	157	May 24	May 5
16	SouthPeace	136	170	May 18	Apr 19

Chapter V. SEEDING DATES AND GROWTH DURATIONS

I. Introduction

Seeding date and crop growth duration are key parameters to describing crop phenology. Seeding date defines the appropriate time to seed the crop based on soil and climate conditions. Growth duration refers to the crop life cycle. It is mainly influenced by temperature and changes considerably with crop types.

Seeding date on the prairies vary considerably from year to year and from one location to another due to variation in weather and soil characteristics. These changes have impact on growth and duration and other physiological stages such as heading and ripening. Consequently yield and quality can be affected (Bootsma and De Jong, 1988).

Predicting seeding date and growth duration is necessary in climate change studies because seeding date is a key input to crop models and growth duration can help to find genotypes with desired growth period that enable farmers to optimize yields (Ritchie and NeSmith, 1991). The objective of this study was to use an empirical seeding date model and the crop phenology submodel of EPIC to predict spring wheat seeding date and growth duration for corn, spring wheat, winter wheat and canola, under actual climate and climate scenarios generated from the Canadian general circulation model (GCM).

II. Methods

IIa. Climate data

Thirty years (1960-1989) of daily weather data including incoming solar radiation (MJ/m^2), maximum and minimun temperatures (°C), rain (mm), snowfall (mm) and total precipitation (mm) were obtained from the climate component of the project (Barr and McGinn, 1994; McGinn et al., 1995). Historical weather data were downscaled at grids of approximatively 50 km resolution. Parameters were estimated based on the nearest neighbour approach and the inverse distance squared method (McGinn et al., 1995). One hundred sixty six grid points with complete weather data were selected for this study (Figure 2).

The local effects of global warming are difficult to predict with general circulation models since each grid point encompasses such a large area (Richard et al., 1990). Therefore the climate

component of the overall project used an interpolation approach within the GCM gridbox (350 km resolution) to generate climate scenarios at grids of 50 km resolution. The scenarios were based on historical temperature and precipitation and estimated temperature and precipitation from the Canadian Climate (GCM) $1XCO_2$ and $2XCO_2$ runs (Saunders and Byrne 1993; Saunders and Byrne 1994; McGinn et al., 1995). The authors used a method similar to Mearns et al. (1992) to alter variance and amplitude of historical climate data. Amplitude change was performed based on GCM $1XCO_2$ and $2XCO_2$ estimates and variances were based on the GCM predicted variance and a random selection of variances (Table V-1). We selected two scenarios; scenario 5 (SN5) with historical precipitation and no change in variance for temperature and scenario 4 (SN4) with GCM predicted variance for temperature and precipitation (Table V-(1-2)).

For spatial analysis of climate parameters, a cosine curve was fitted on the 30 years of temperature to generate mean daily temperature (T) for each scenario:

$$T = a + b*\cos[0.017457*(doy-d_o)]$$

a and b are regression coefficients, where a represents the annual mean maximum or minimum temperature, doy is the day of the year (Julian) and d_o, the offset, represents the 30 years average julian day when temperature reached maximum. d_o was the offset calculated for each weather grid box.

For each grid point, average annual total precipitation was also calculated.

IIb. Models

We developed an empirical seeding model (Major et al.,1995) from which output was used to run the EPIC (Erosion Productivity Impact Calculator; Williams et al. 1990) model to calculate various crop yields and growth durations. The seeding date model was based on 60 years of seeding dates obtained from a rotation experiment initiated in 1911 at the Agriculture Canada Lethbridge Research Center (LRC). Daily values of maximum and minimum temperatures, precipitation and solar radiation were recorded at the LRC weather station located within 500 m of the experimental site.

A trial and error approach was used, in which maximum temperature had to exceed 13°C, precipitation had to be less than 0.5 mm and the fraction of evaporable soil moisture had to be less than 90% of field capacity level for 4 consecutive days. Optimization of each of these parameters

was conducted to obtained the final model with the minimum difference between predicted and actual seeding dates.

The model predicted 60 years (1930-1989) mean seeding date with good accuracy. The difference between average observed and estimated seeding date was a day. In spite of the significant correlation between observed and predicted seeding date, the coefficient of determination was only 0.20 suggesting that many points did not fit well. Nevertheless we used this model as long term mean is a representative parameter to investigate issue such as climate change (Kiniry et al. 1995).

Since the begining of the simulation affects estimated seeding dates, we utilized the winter wheat regrowth dates (see Chapter IV) and initialize the model 10 days before that event.

We selected the EPIC model to predict the impact of climate change on crop growth and development (Touré et al. 1995a and b). Thus we used the same model to evaluate crop growth duration under changing climate. The EPIC model required seeding date and potential heat unit (PHU) to determine crop growth duration which refers to the time from seeding to maturity. Physiological maturity is reached when accumulated heat unit, calculated from daily average temperature minus the crop base temperature, equal PHU. Table VI-6 presents PHU used for crops considered in this study.

IIc. Outputs

As with agroclimatic indices, a series of shell scripts were written to access the 166 weather grid points that contained complete data for the 30 year period. The shell script consisted of a VMS command program (Appendix A-V.xa) which called a SAS program (Appendix A-V.xb) to calculate seeding dates at the selected grid points. Similar programing approach (detailed in chapter VI) was used to calculate crop growth duration using the EPIC model. The command programs were run for the historical (SN6) and the $2XCO_2$ (SN4 and SN5) scenarios.

The geographic coordinates (latitude and longitude) of each grid were converted to UTM coordinates in the GRASS (Geographic Resources Analysis System) GIS to create sites files containing UTM coordinates and corresponding parameter. Other shell scripts in the ULTRIX environment were written (Appendix A-VI.2) to create raster and vector maps for each parameter and scenario combinations.

III. Results

IIIa. Climate data

Annual mean total precipitation: Average historical total precipitation was 481±95 mm across Alberta (Table V-3a) with high total precipitation in the west (mountain area) and low total precipitation in the south east of the province. The GCM predicted scenario (SN4) was 28% higher than current. For SN5, historical total precipitation was maintained.

Annual mean maximum temperature: The historical mean maximum temperature over the 30 years and averaged across the province was 8.5 °C (Table V-3b). Temperature was inversely related to latitude with a maximum of 12 °C in the south and minimum of 4°C in the north. Changes relative to historical temperature suggested by the scenarios are generally similar. Both scenarios predicted a 4°C increase with higher increase in winter (Table V.4c).

IIIb. Seeding date

Table V-4a and b present seeding dates statistics and average by Crop Reporting Districts. Average seeding dates for Alberta were April 25 (Julian day 115), April 28 (Julian day 118) and May 18 (Julian day 138) for SN4, SN5 and SN6, respectively. Under climate change, the results showed that average seeding date for the province was 24 and 21 days earlier to actual for scenarios 5 and 4. For example, the Medecine Hat area will be seeded earlier by as much as one month, shifting from May 5 (SN6) to April 5 (SN5) and April 8 (SN4). Similar results were reported by Brklacich et al. (1992).

Seeding date changes across the province with seeding occuring earlier in the south and later in the north and west.

IIIc. Growth duration

Table V-5 and Table V-(5a-d) present growth duration statistics for the province and averaged by Crop Reporting Districts. Climate scenarios have significant effects on growth duration. Average growth duration was reduced for the crops investigated in this study. Corn was the most affected with 22 days shorter (SN4) followed by canola and spring wheat. Similar change was observed for spring wheat with 13 and 14 days shorter under SN5 and SN4.

As seeding date, growth duration changes across the province with shorter growth duration

in the south and longer in the north and west.

IV. Discussions

Climate warming by 4°C had significant effects on seeding date and crop growth durations, consequently on field operations which will start earlier. These changes were not uniform across the province as assumed in previous modeling experiments (Bootsma et al. 1984; Williams et al. 1988; Brklacich et al. 1991). Scenario 4 and 5 have similar seeding date and growth duration distributions, suggesting that temperature was the main factor controlling these two parameters, speeding up growth duration and forcing earlier seeding than current.

Shorter growth duration than actual may impact crop yields as this change was reported to reduce leaf area duration, decrease seasonal interception of photosynthetically active solar radiation and reduce yields (Amir and Sinclair 1991; Brklacich et al. 1991; Stockle et al. 1992).

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Table V-1 : Ratio of variances and corresponding climate scenarios (SN).

Ratio of variances	0.5[t]	1[t]	2[t]	GCM[t]	Historical temperature
0.5[p]	SN1				
1[p]		SN2			
2[p]			SN3		
GCM[p]				SN4	
Historical precipitation		SN5			Baseline (SN6)

[t] : ratio of variances used to alter historical temperature.

[p] : ratio of variances used to alter historical precipitation.

Table V-2a: Annual mean total precipitation (mm) statistics for Alberta according to the scenarios.

Scenarios	Mean	Std.	Min.	Max.	% Change
SN4 GCM variance	618	120	382	958	28
SN5 Hist. variance	481	95	291	740	0
SN6 Hist. Variance	481	95	291	740	

Table V-2b: Annual mean maximum temperature (°C) statistics for Alberta according to the scenarios.

Scenarios	Mean	Std.	Min.	Max.	Δ
SN4 GCM variance	12.3	2.1	7	17	3.8
SN5 Hist. variance	12.2	2.1	7	17	3.7
SN6 Hist. Variance	8.5	1.7	4	17	

Table V-3: Climate scenarios mean monthly maximum and minimum temperatures (°C) and total precipitation (mm) changes from historical (1x; SN6) for Lethbridge grid point "BD45".

	SN6			SN4-SN6		SN5-SN6		SN4/SN6
	Tmax.	Tmin.	Precip.	Tmax.	Tmin.	Tmax.	Tmin.	Precip.
Month								
1	-2.9	-14.6	22.9	5.5	10.0	5.6	10.0	1.66
2	0.8	-11.1	14.6	5.4	10.0	5.4	9.9	1.42
3	5.1	-7.2	25.1	4.1	9.7	4.3	9.5	1.35
4	12.2	-1.1	35.9	7.4	7.5	6.8	8.1	1.17
5	18.1	4.3	49.3	7.7	6.1	7.7	6.1	1.76
6	22.6	8.7	65.0	4.0	4.1	4.0	4.1	1.10
7	26.0	10.6	37.0	2.9	3.7	2.9	3.7	1.08
8	25.3	9.6	42.9	4.5	4.3	4.4	4.3	1.19
9	19.4	4.9	41.1	3.5	3.3	3.5	3.3	1.32
10	14.3	0.4	15.9	3.5	2.0	3.5	2.0	1.02
11	4.5	-7.4	17.0	4.0	1.7	3.6	2.2	1.10
12	-1.0	-12.3	22.1	2.6	6.5	2.7	6.4	1.31

Table V-4a. Estimated seeding date averaged over the weather grid points across Alberta for historical (1x) and doubled (2x) atmospheric CO_2 concentrations (SN4 and SN5).

	Mean	Std	Minimum	Maximum	(SNX-SN6)
SN4	April 28	11	March 23	May 21	-21
SN5	April 25	12	March 12	May 19	-24
SN6	May 19	9	April 24	June 6	

Table V-4b: Seeding dates averaged by Alberta Crop Reporting Districts for historical (1x; SN6) and doubled (2x; SN4 and SN5) atmospheric CO_2 concentrations.

		Crop Reportind District	SN6	SN5	SN4	(SN5-SN6)	(SN4-SN6)
1	CD1	MedicineHat/Foremost	May 6	Apr 5	Apr 9	-31	-27
2	CD2	Lethbridge/Brooks	May 2	Apr 4	Apr 11	-28	-21
3	CD3	Claresholm/Cardston	May 5	Apr 6	Apr 13	-30	-23
4	CD4	Hanna/Empress	May 17	Apr 19	Apr 21	-28	-27
5	CD5	Drummheller/Vulcan	May 11	Apr 15	Apr 21	-26	-20
6	CD6	Calgary/Old	May 11	Apr 16	Apr 19	-25	-22
7	CD7	Stettler/Wainwright	May 21	Apr 24	Apr 26	-27	-25
8	CD8	RedDeer	May 16	Apr 21	Apr 24	-25	-23
9	CD9	RockyMountain-region	May 21	Apr 27	Apr 28	-24	-22
10	CD10	Camrose/Vermilion	May 2	Apr 27	Apr 30	-24	-21
11	CD11	Edmonton	May 20	Apr 24	Apr 28	-26	-23
12	CD12	LacLaBiche/StPaul	May 25	May 11	May 12	-14	-13
13	CD13	Barrheah/Athabasca	May 24	Apr 28	May 2	-26	-22
14	CD14	Edmonton-West	May 22	Apr 27	Apr 30	-25	-22
15	CD15A	NorthPeace	May 25	May 13	May 13	-12	-12
16	CD15B	SouthPeace	May 22	May 4	May 6	-18	-16

Table V-5: Estimated crop growth duration (days) averaged over weather grid points across Alberta for historical (1x; SN6), and doubled (2x) atmospheric CO_2 concentrations (SN4 and SN5).

	Mean			Minimum			Maximum			Dif.	
Crop	SN6	SN5	SN4	SN6	SN5	SN4	SN6	SN5	SN4	1	2
Canola	95	83	81	81	73	71	101	98	98	-12	-14
Spring wheat	101	88	87	85	77	75	109	107	107	-13	-14
Winter wheat	147	143	135	128	128	116	197	178	169	-4	-12
Corn	110	102	100	90	86	83	125	133	133	-20	-22

1: SN5-SN6

2: SN4-SN6

Table V-6a: Estimated growth duration for canola averaged by Alberta Crop Reporting Districts for historical (1x; SN6) and doubled (2x; SN4 and SN5) atmospheric CO_2 concentrations.

		Crop Reporting Districts	SN6	SN5	SN4	(SN5-SN6)	(SN4-SN6)
1	CD1	MedicineHat/Foremost	88	80	76	-8	-12
2	CD2	Lethbridge/Brooks	91	81	76	-10	-15
3	CD3	Claresholm/Cardston	96	90	86	-6	-10
4	CD4	Hanna/Empress	87	76	75	-11	-12
5	CD5	Drummheller/Vulcan	93	81	78	-12	-15
6	CD6	Calgary/Olds	97	91	89	-6	-8
7	CD7	Stettler/Wainwright	92	77	76	-15	-16
8	CD8	RedDeer	97	87	86	-10	-11
9	CD9	RockyMountain-region	97	94	93	-3	-4
10	CD10	Camrose/Vermilion	95	76	75	-19	-20
11	CD11	Edmonton	98	82	80	-16	-18
12	CD12	LacLaBiche/StPaul	98	81	80	-17	-18
13	CD13	Barrheah/Athabasca	99	84	82	-15	-17
14	CD14	Edmonton-West	98	93	91	-5	-7
15	CD15A	NorthPeace	98	81	80	-17	-18
16	CD15B	SouthPeace	99	85	84	-14	-15

Table V-6b: Estimated growth duration for spring wheat averaged by Alberta Crop Reporting Districts for historical (1x; SN6) and doubled (2x; SN4 and SN5) atmospheric CO_2 concentrations.

		Crop Reporting Districts	SN6	SN5	SN4	(SN5-SN6)	(SN4-SN6)
1	CD1	MedicineHat/Foremost	93	84	81	-9	-12
2	CD2	Lethbridge/Brooks	96	86	82	-10	-14
3	CD3	Claresholm/Cardston	105	95	91	-10	-14
4	CD4	Hanna/Empress	91	81	80	-10	-11
5	CD5	Drummheller/Vulcan	97	86	83	-11	-14
6	CD6	Calgary/Olds	106	97	95	-9	-11
7	CD7	Stettler/Wainwright	95	83	82	-12	-13
8	CD8	RedDeer	104	93	91	-11	-13
9	CD9	RockyMountain-region	108	102	101	-6	-7
10	CD10	Camrose/Vermillion	98	82	81	-16	-17
11	CD11	Edmonton	102	87	86	-15	-16
12	CD12	LacLaBiche/StPaul	102	86	85	-16	-17
13	CD13	Barrheah/Athabasca	104	89	87	-15	-17
14	CD14	Edmonton-West	108	97	96	-11	-12
15	CD15A	NorthPeace	104	86	86	-18	-18
16	CD15B	SouthPeace	105	89	89	-16	-16

Table V-6c: Estimated growth duration for winter wheat averaged by Alberta Crop Reporting Districts for historical (1x; SN6) and doubled (2x; SN4 and SN5) atmospheric CO_2 concentrations.

		Crop Reporting Districts	SN6	SN5	SN4	(SN5-SN6)	(SN4-SN6)
1	CD1	MedicineHat/Foremost	139	136	131	-3	-8
2	CD2	Lethbridge/Brooks	143	135	131	-8	-12
3	CD3	Claresholm/Cardston	160	142	140	-18	-20
4	CD4	Hanna/Empress	132	136	128	4	-4
5	CD5	Drummheller/Vulcan	142	142	134	0	-8
6	CD6	Calgary/Olds	161	153	147	-8	-14
7	CD7	Stettler/Wainwright	135	139	129	4	-6
8	CD8	RedDeer	153	151	142	-2	-11
9	CD9	RockyMountain-region	170	161	155	-9	-15
10	CD10	Camrose/Vermilion	136	137	127	1	-9
11	CD11	Edmonton	146	144	135	-2	-11
12	CD12	LacLaBiche/StPaul	142	137	127	-5	-15
13	CD13	Barrheah/Athabasca	149	143	133	-6	-16
14	CD14	Edmonton-West	167	155	145	-12	-22
15	CD15A	NorthPeace	143	136	125	-7	-18
16	CD15B	SouthPeace	151	144	135	-7	-16

Table V-6d: Estimated growth duration for corn averaged by Alberta Crop Reporting Districts for historical (1x; SN6) and doubled (2x; SN4 and SN5) atmospheric CO_2 concentrations. 0 represents areas without sufficient heat for corn to growth under current climate.

		Crop Reporting Districts	SN6	SN5	SN4	(SN5-SN6)	(SN4-SN6)
1	CD1	MedicineHat/Foremost	109	92	89	-17	-20
2	CD2	Lethbridge/Brooks	112	94	90	-18	-22
3	CD3	Claresholm/Cardston	0	108	104	0	0
4	CD4	Hanna/Empress	110	91	90	-19	-20
5	CD5	Drummheller/Vulcan	114	97	94	-17	-20
6	CD6	Calgary/Olds	0	113	111	0	0
7	CD7	Stettler/Wainwright	0	94	93	0	0
8	CD8	RedDeer	0	109	108	0	0
9	CD9	RockyMountain-region	0	119	118	0	0
10	CD10	Camrose/Vermilion	0	94	93	0	0
11	CD11	Edmonton	0	101	100	0	0
12	CD12	LacLaBiche/StPaul	0	104	104	0	0
13	CD13	Barrheah/Athabasca	0	108	107	0	0
14	CD14	Edmonton-West	0	120	119	0	0
16	CD15B	SouthPeace	0	114	113	0	0

Chapter VI. CROP YIELDS

I. Introduction

Agriculture plays a key role in Alberta's economy. There are good indications that carbon dioxide and other trace gases in the earth's atmosphere are increasing with the prediction that average annual global temperature will increase 2.8 to 5.2 ℃ and precipitation will increase 7 to 32% for a doubled atmospheric carbon dioxide concentration (Hansen et al. 1984; Wong et al. 1989; Drennen and Kaiser, 1993). While these changes will have a large effect on crop production, predicting its impact on agriculture will permit steps to be taken to avoid serious dislocations.

Plant growth is dependent on many factors including heat, water, nutrient and atmospheric CO_2 concentrations. For example, for a given soil condition, crop yield is expected to increase up to an optimum temperature and decrease thereafter. A similar dynamic is applicable to precipitation effect on yields (Touré et al., 1995b). If any plant growth factor is in short supply, growth will be slowed or plant survival itself will be jeopardized (Wolfe and Erickson, 1993). Changes in atmospheric CO_2 concentration will impact plant growth in two ways. First, CO_2 will directly affect plant photosynthetic activities. In controlled experiments, C3 species, such as wheat, canola and many weeds, show significant gains in net photosynthesis because of photorespiration inhibition. C4 plants including corn, and sorghum, show a reduced response to increased CO_2 due to a more efficient carbon assimilation process (Rosenzweig, 1990; Wolfe and Erickson, 1993). Second, the CO_2-induced greenhouse effect will warm the surface and the lower atmosphere and change the climatic regime. Consequently, available soil water and heat for plant growth will be affected.

Computer simulation models offer an opportunity to speculate on crop production strategies. Several modeling studies have examined climate change on the prairies, but only for specific crops at specific sites, assuming similar seeding dates under current climate and climate scenarios (Bootsma et al. 1984; Williams et al. 1988; Brklacich et al. 1991). However Canadian agriculture covers large areas with several soil and climate zones, suggesting a non-uniform distribution of climate change effect on crops. In addition, there is evidence that seeding date is affected by climate variables (Brklacich et al. 1992; Major et al. 1995).

The objective of this study was to examine the spatial variability of corn, winter wheat, spring wheat, canola, and crested wheatgrass in Alberta under climate change using the EPIC model coupled to the GRASS GIS (geographic information system). The linkage of ecosystem simulation

models to GIS provides the technological support for analyzing spatial variability in ecosystem properties and processes.

II. Methods

IIa. Model selection

Potential changes in crop yields at several weather grid points across Alberta were estimated using EPIC. The choice of this model was based on several criteria. First, the EPIC model simulates crop response to the major climate variables of temperature, precipitation and solar radiation, and includes the effect of soil characteristics on water availability for crop growth. Second, it is a versatile model that can simulate various crop rotations and tillage practices and has been modified to include the effect of atmospheric CO_2 concentrations on crop growth (Easterling et al., 1992; Stockle et al., 1992). Third, EPIC was validated for a wide range of soil and climatic conditions in Canada and the USA (Moulin and Beckie, 1993; Kiniry et al., 1995; Touré et al., 1995a), demonstrating that it simulates long-term mean yield with good precision. However, the relationship between observed and predicted yields has suggested that the model may not adequately represent year to year variability (Moulin and Beckie, 1993; Touré et al., 1995a). Nevertheless its ability to predict long term mean yield with good accuracy makes it a good tool for climate change assessment which is based on long term prediction (Kiniry et al. 1995). Fourth, compared to widely used crop growth models including CERES, Century, Stewart and Sinclair models, using data from a long term experiment begun in 1911 at Lethbridge, AB, the EPIC model gave the best simulation results over all rotations including continuous wheat, fallow-wheat and fallow-wheat-wheat (Touré et al. 1995a,b). Mean yield differences from current ranged from 1-29 g/m^2 and coefficient of correlations ranged from 0.36-0.77, depending on the rotation.

IIb. Model inputs

Daily climate, crop and soil parameters are driving variables for production to perform simulation. These parameters are described below.

Climate data: The same dataset used to simulate seeding date were utilized in this study. The reader should refer to chapter IV for a detail description of the dataset.

Crop data: The crop growth subroutine in EPIC simulates crop growth described by parameters related to leaf area and photochemical efficiency. Values for corn, winter wheat, spring wheat, canola and crested wheatgrass (Table VI-1) were based on previous evaluations of the model on the prairies (Bouzaher et al., 1994; Touré et al., 1995a; Kiniry et al., 1995).

Photosynthetic rates were increased by 10% and 25% for C4 (corn) and C3 (winter wheat, spring wheat, canola, crested wheatgrass) species for $2XCO_2$ equivalent. These values were reported for controlled experiments where water, nutrient, temperature, and pest pressure were optimum (Richard et al., 1990; Mearns et al. 1990). However Cure an Acock (1986) reported that low nutrient concentrations limited the responses of most crops to CO_2.

Seeding date is a key parameter in modeling crop growth. It is affected by climate change as temperature and precipitation are the main parameters controlling crop development (Stewart et al., 1990). An empirical seeding date model (Major et al., 1995), presented in chapter V, was developed based on long term spring wheat data. Predicted seeding dates from this model were used as input to the EPIC model. The estimated spring wheat seeding date was assumed for corn, canola and crested wheatgrass. Seeding date for winter wheat was 137 days after spring wheat was seeded, based on the seeding date lag between both crops in Lethbridge (Kenneth et al. 1988; Major et al., 1995). Maturity is reached when accumulated heat from seeding date equals potential heat units (PHU; accumulation of heat with the substraction of a x ^{0}C base temperature). Harvest time was set a week later for all the crops except corn. Heat requirement for this crop imposed a more detailed approach to calculate maturity and harvest times. We used a linear relationship obtained by Major (1980) between percent kernel moisture (kern) and growing degree day (GDD) with a base of 12°C:

$$kern = 126.7 - 0.242(GDD_{12}) \quad R^2 = 0.96$$

We converted GDD_{12} into GDD_8 from the following linear relationship between both parameters.

$$GDD_8 = 665.4 + 1.09(GDD_{12}) \quad R^2 = 0.98$$

PHU was then calculated using GDD_8, from seeding till 35% of kernel moisture which was assumed to be the corn physiological maturity and harvest time was 25% of kernel moisture (Major, 1980). Grid points with a PHU less than GDD_8 required to reach physiological maturity were not used for simulation.

Soil data: Soil attributes were extracted from the Canadian Soil Information System (CanSIS) database (Shields et al., 1991) and Tajek (1995, personal communication). This was done by overlaying weather grid points and soil polygons in the GRASS GIS. Table VI-2 presents input soil parameters for EPIC. Field capacity was calculated based on the available soil water (ASW in upper 120 cm) and soil wilting point (WP; 0.1 was assumed):

$$FC = ASW/120 + WP$$

Missing soil data were estimated by the EPIC model. A sensitivity of the model to these parameters relative to the Lethbridge grid point was performed. The test did not detect any change in yield run without the missing values compared to the run with these data. This suggested that the model could be run without these parameters. From the 166 grid points (Figure 2), only 136 had complete soil parameters to run the EPIC model.

IIc. Outputs

Similar to the approach used to generate agroclimatic indices, a series of shell scripts were written to create input files and execute EPIC for each of the 136 grid points. The shell script consisted of a VMS command program (Appendix A-VI) which called a fortran program to extract climate data, soil, seeding date and management data for each subsoil in a grid. This was repeated for the 136 grid points. With different subsoils in a grid box, 412 input files were created for a given crop, climate condition and soil types. Only 20 grids had enough heat to allow corn to reach maturity under historical climate. This number was up to 98 for climate scenarios because of increased temperature.

The EPIC model was then executed to generate output files containing geographic coordinate of grid points, subsoils, 30 year mean yields, standard deviation and crop growth duration. Average yield by grid was then calculated using a weighting average approach based on the subsoil area within a grid. The command programs were run for the historical (SN6) and the climate scenarios (SN5 and SN4).

The geographic coordinates (latitude and longitude) of each grid were converted to UTM coordinates in the GRASS (Geographic Resources Analysis System) GIS to create sites files containing UTM coordinates and corresponding parameter. Other shell scripts in the UNIX environment were written (Appendix A-VI) to create raster and vector maps. Raster maps were generated by filling in each map cell with interpolated data, based on yields in surrounding grids and

their inversed squared distance. Categories were created by regrouping yields in classes of 50 g/m^2.

The raw values for the crop yields for each grid point are listed in Appendix B-VI. Additional reports were generated to determine the concordance of the agroclimatic index with the Regional Municipalities of Alberta (Appendix C-VI), for each of the Crop Reporting Districts of Alberta (Table VI) and for Soil Landscape of Canada (Appendix D-VI).

III. Results

Results of crop simulations under historical and climate scenarios are presented in Table VI-3 for crop yield statistics for the province and Tables VI-(4-6) for crop yields averaged by Crop Reporting Districts.

Dryland continuous crops: For most of the crops, yield increases with latitude, especially with corn. Maximum yields were obtained in Edmonton and Camrose/Vermilion areas, except corn, and minimum yields in Medicine Hat and Hanna/Empress area for crested wheatgrass.

Scenario 5 and 4 have positive effect on yield with the highest average increase predicted by SN4 because of increase in precipitation. Corn will benefit the most from the warming climate with yield more than doubled under SN4 while spring wheat showed the lowest increase, 27% under SN5. According to both scenarios, some weather grid boxes will experience losses as much as 38% for crested wheatgrass and slight losses with canola, less then 10%.

Fallow-crop rotations: Under the climate change scenarios, crops following fallow had a similar predicted yield distribution to continuous cropping, but higher yields and higher increases because of higher soil moisture. A future climate with increased precipitation was more beneficial than the one with increased temperature alone for canola in almost all crop reporting districts. Similar results applied to winter and spring wheat but only for drier southern soils. For districts located in the north and west of the province, there was a decrease in yield with SN4 compared to SN5 because of nutrient stress. Winter wheat had a higher yield increase and maintained its high yielding capability compared to spring wheat, in part due to earlier regrowth and reduced risk of winter kill. The reverse was true for spring wheat at districts located south. Changes in yield for fallow cropping compared to continuous cropping varied with crop type and location. For canola, results showed higher predicted yield for the crop fallow rotation but the reverse was true for spring wheat and corn. Changes in average spring wheat yield decrease from 34% for continuous cropping to 27% for fallow cropping under SN4.

Irrigated crops: All the crops had low variability in yields and high yields across the province because of limited water stress. Both scenarios predicted yield increase at all locations. However, inspite of the precipitation differences, they predicted similar yield increase for a given crop. Canola will benefit the most with 40% increase under SN4 and the lowest increase will be observed with corn, 2% under SN5.

IV. Discussion

As suggested by their effect on seeding dates and growth durations, climate change will have a significant impact on crop yields. Predicted higher temperature (SN5) and higher precipitation and temperature (SN4) than current will be beneficial to most of the crops we investigated in this study. Higher dryland yields were predicted compared to irrigated crops and crops after fallow. This is because of low dryland yields under current climate, specially in the southern areas of the province where moisture is limiting.

Dryland crops seeded to stubble were very sensitive to high temperature because of increased water stress. However, the results showed beneficial effects of the climate scenarios on yields because of the fertilizing effect of CO_2 that was assumed in our simulations. Also, some crops may not be at their optimum and increases in temperature may be beneficial for those crops according to EPIC.

Climate warming may result in shifting cropping practices. Spring wheat showed higher yield than winter wheat for fallow cropping under SN4 because of increased precipitation, suggesting that the shift from winter wheat to spring wheat may help to take advantage of the warming effect. Also, irrigation practices can help to alleviate yield loss especially for canola.

Limitations on this study should lead to putting the results into perspective. There are several sources of uncertainty in any future scenario prediction. The EPIC model underestimates year-to-year variability in yield (Touré et al. 1995a) which may be significant if future climate exhibits greater variability. In addition we assumed, in our simulation, parameters derived from controlled experiments which may not be valid under field situation where water, nutrient, temperature, and pest pressure are limiting. Also, because of lack of data, we assumed 5% loss in yields due to insect damages under current climate and climate scenarios. However, a warmer climate is expected to allow pest and diseases that were previously constrained to low latitudes to move northward to create more damage to crops.

The ability of GCM to simulate current climate varies considerably from region to region due to local differences (Mearns et al. 1992; Cess et al. 1993). Perhaps the greatest uncertainty in using GCM is that they simulate current surface air temperatures reasonably well, but not precipitation (Rosenzweig and Parry 1993).

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Table VI-1. Crop parameters selected for EPIC simulations.

Parameter	Description	Corn	W. wheat	S. wheat	Canola	C. wheatgrass
WA :	Biomass-energy ratio at 330 ppm CO_2 (Kg/ha/MJ)	40.0	33.0	31.0	34.0	35.0
RUEC2 :	Second point on RUE-CO_2 curve. Number before decimal is a hign CO_2 level of the future (ppm). Number after decimal is the resulting RUE value times 10.	660.44	660.41	660.39	660.42	660.44
HI :	Harvest index (Kg/Kg)	0.55	0.50	0.42	0.30	0.03
T_b :	Optimal temperature for plant growth (°C)	25.0	18.0	18.0	21.0	25.0
T_g :	Minimum temperature for plant growth (°C)	8.0	0.0	0.0	5.0	6.0
DMLA :	Maximum potential leaf area index	6.5	5.0	5.0	4.5	5.0
DLAI :	Fraction of growing season when leaf area starts declining	0.70	0.50	0.60	0.50	0.85
DLAP1, 2 :	Two points on optimal leaf area development curve. Numbers before decimal are percent of growing season. Numbers after decimal are fractions of maximum leaf area index (%)	15.05	5.05	15.01	15.02	35.02
DLAP2 :		50.95	45.95	50.95	45.95	62.95
RLAD :	Leaf area decline rate parameter	1.0	0.5	1.0	0.15	2.0
RBMD :	Biomass-energy ratio decline rate parameter	1.0	1.0	1.0	0.3	1.0
ALT :	Aluminum tolerance index (1-sensitive;5-tolerant)	3.0	2.0	2.0	2.0	2.0
CAF :	Critical aeration factor	0.85	0.85	0.85	0.85	0.85
HMX :	Maximum crop height (m)	2.5	1.2	1.2	0.9	1.3
RDMX :	Maximum root depth (m)	2.0	1.2	1.2	0.9	1.3
CVM :	Maximum value of C factor for water erosion	0.20	0.03	0.03	0.03	0.03
CNY :	Fraction of nitrogen in yield	0.014	0.025	0.025	0.38	0.023
CPY :	Fraction of phosphorus in yield	0.0016	0.0022	0.017	0.079	0.004
WSYF :	Fraction of water in yield	0.20	0.190	0.190	0.17	0.01
PST :	Pest (insects, weeds and desease) factor	0.95	0.95	0.95	0.95	0.95
WCY :	Fraction of phosphorus in yield	0.15	0.12	0.12	0.08	0.12
IDC :	Crop category number; 4 = Warm-season annual crop 5 = Cold-season annual crop 6 = Perennial crop	4	5	5	5	6
BN1 :	Nitrogen uptake parameter (P fraction in plant at emergence)	0.047	0.06	0.06	0.044	0.06
BN2	Nitrogen uptake parameter (N fraction in plant at 0.5 maturity)	0.0177	0.023	0.023	0.0164	0.02
BN3	Nitrogen uptake paramter (N fractionin plant at maturity)	0.0138	0.0134	0.0134	0.0128	0.012
BP1	Phosphorus uptake parameter (P fraction in plant at emergence)	0.0048	0.0084	0.0084	0.0074	0.002
BP2	Phosphorus uptake parameter (P fraction in plant at 0.5 maturity)	0.0018	0.0032	0.0032	0.0037	0.0015
BP3	Phosphorus uptake parameter (P fraction in plant at maturity)	0.0014	0.0019	0.0019	0.0023	0.013
FRST1:	Two points on frost damage curve. Numbers before decimal are minimum daily temperature (°C). Numbers after decimat are fractions of lai loss for given minimum temperature	5.150	15.050	5.01	5.05	5.01
FRST2 :		15.95	30.10	15.01	15.10	15.01
PHU :	Potential heat units (degree-day)	996	1800	1500	1000	1000

Table VI-2a: Soil attributes used to run the EPIC model; data represent the subsoil "ABC" pertaining to the gray lusovic group.

	Parameter	Value					
1.	Depth from surface to the bottom	0.01	0.18	0.23	0.58	0.91	1.00
2.	Bulk density of soil layer (t/m^3)	1.30	1.30	1.30	1.50	1.50	1.50
3.	Wilting point* (m/m)	0	0	0	0	0	0
4.	Field capacity* (m/m)	0	0	0	0	0	0
5.	Sand content (%)	45.0	45.0	43.0	41.0	42.0	43.0
6.	Silt content (%)	30.0	30.0	29.0	27.0	28.0	29.0
7.	Organic N concentration* (g/t)	0	0	0	0	0	0
8.	Soil PH	5.2	5.2	4.6	4.3	4.9	5.5
9.	Sum of bases (cmol/kg)	16.8	16.8	9.6	14.4	14.9	15.6
10.	Organic carbon (%)	2.00	2.00	0.40	0.40	0.40	0.50
11.	Calcium carbonate* (%)	0	0	0	0	0	0
12.	Cation exchange capacity (cmol/kg)	24.0	24.0	13.0	15.0	18.0	17.0
13.	Coarse fragment content (% vol)	5.0	5.0	5.0	5.0	5.0	5.0
14.	Nitrate concentration* (g/t)	0	0	0	0	0	0
15.	Labile P concentration* (g/t)	0	0	0	0	0	0
16.	Crop residue* (t/ha)	0	0	0	0	0	0
17.	Bulk density (oven dry)* (t/m^3)	0	0	0	0	0	0
18.	Phosphorus sorption ratio*	0	0	0	0	0	0
19.	Saturated conductivity* (mm/h)	0	0	0	0	0	0
20.	Subsurface flow travel time*	0	0	0	0	0	0
21.	Organic P concentration* (g/t)	0	0	0	0	0	0

*: Parameter not available for all subsoil; they are estimated by the EPIC model.

Table VI-2b: Available soil type used to run EPIC.

Soil group	Soil type	Soil group	Soil type
Black Chernozemic	AGS	Dark Gray Chernozemic/Luvisolic	FRY
Black Chernozemic	ATL	Dark Gray Chernozemic/Luvisolic	MCO
Black Chernozemic	BVH	Dark Gray Chernozemic/Luvisolic	MGS
Black Chernozemic	BZR	Dark Gray Chernozemic/Luvisolic	MLA
Black Chernozemic	CWY	Dark Gray Chernozemic/Luvisolic	PHS
Black Chernozemic	CYG	Dark Gray Chernozemic/Luvisolic	PRV
Black Chernozemic	DEL	Dark Gray Chernozemic/Luvisolic	RDW
Black Chernozemic	DLB	Dark Gray Chernozemic/Luvisolic	RMY
Black Chernozemic	DVG	Dark Gray Chernozemic/Luvisolic	SAD
Black Chernozemic	EOR	Dark Gray Chernozemic/Luvisolic	SDN
Black Chernozemic	FRY	Dark Gray Chernozemic/Luvisolic	SPR
Black Chernozemic	HBM	Dark Gray Chernozemic/Luvisolic	TAG
Black Chernozemic	HND	Dark Gray Chernozemic/Luvisolic	UCS
Black Chernozemic	IRM	Dark Gray Chernozemic/Luvisolic	WTB
Black Chernozemic	LAD	Dystric Brunisolic	TMN
Black Chernozemic	MGS	Eutric Brunisolic	CAR
Black Chernozemic	MMO	Eutric Brunisolic	RDW
Black Chernozemic	NVR	Gleysolic	COD
Black Chernozemic	PED	Gray Luvisolic	ABC
Black Chernozemic	PHS	Gray Luvisolic	BTN
Black Chernozemic	POK	Gray Luvisolic	CAR
Black Chernozemic	RDW	Gray Luvisolic	COA
Black Chernozemic	RMY	Gray Luvisolic	CTE
Black Chernozemic	WWT	Gray Luvisolic	DON
Black Solonetzic	CMO	Gray Luvisolic	DVS
Black Solonetzic	GDB	Gray Luvisolic	ESH
Black Solonetzic	KLM	Gray Luvisolic	GDI
Black Solonetzic	KVG	Gray Luvisolic	GOG
Black Solonetzic	MCO	Gray Luvisolic	HUB
Black Solonetzic	MMO	Gray Luvisolic	LCY
Black Solonetzic	VVW	Gray Luvisolic	LOB
Black Solonetzic	WKN	Gray Luvisolic	MYW
Brown Chernozemic	ACV	Gray Luvisolic	PNC
Brown Chernozemic	BVL	Gray Luvisolic	SDN
Brown Chernozemic	CCL	Gray Luvisolic	TMN
Brown Chernozemic	CFD	Gray Luvisolic	TNW
Brown Chernozemic	CHN	Gray Solonetzic	KVG
Brown Chernozemic	CVD	Regosolic	ATP
Brown Chernozemic	FMT		
Brown Chernozemic	MAB		
Brown Chernozemic	MSN		
Brown Chernozemic	TIY		
Brown Solonetzic	HDY		
Brown Solonetzic	HUK		
Brown Solonetzic	SIL		
Brunisolic Gray Luvisolic	LOB		
Dark Brown Chernozemic	CRD		
Dark Brown Chernozemic	DMH		
Dark Brown Chernozemic	HAN		
Dark Brown Chernozemic	HND		
Dark Brown Chernozemic	LET		
Dark Brown Chernozemic	PUR		
Dark Brown Chernozemic	RDM		
Dark Brown Chernozemic	WWT		
Dark Brown Solonetzic	HKR		
Dark Gray Chernozemic/Luvisolic	ATO		
Dark Gray Chernozemic/Luvisolic	CVL		
Dark Gray Chernozemic/Luvisolic	DVG		
Dark Gray Chernozemic/Luvisolic	ESH		
Dark Gray Chernozemic/Luvisolic	FAL		
Dark Gray Chernozemic/Luvisolic	FLU		

Table VI-3a. Estimated dryland continuous crop yields (g/m^2) averaged over the weather grid points across Alberta for historical (1x; SN6) and doubled (2x; SN4 and SN5) atmospheric CO_2 concentrations.

	Mean	Std.	Min.	Max.	SNX/SN6*
Canola					
SN6	196	61	52	284	
SN5	250	60	106	342	1.36 (0.91-3.80)
SN4	268	30	135	324	1.51 (0.95-3.66)
Spring wheat					
SN6	125	19	70	170	
SN5	159	24	108	231	1.27 (1.12-1.81)
SN4	166	21	118	229	1.34 (1.17-1.92)
Corn					
SN6	189	38	130	300	
SN5	477	202	161	851	1.18 (1.01-1.39)
SN4	631	175	232	879	2.12 (1.28-2.55)
Crested wheatgrass					
SN6	384	113	80	591	
SN5	551	209	89	978	1.52 (0.62-6.4)
SN4	585	196	101	968	1.62 (0.66-5.72)

*: Average and range of yield ratio.

Table VI-3b. Estimated fallow-crop rotation yields (g/m^2) averaged over the weather grid points across Alberta for historical (1x; SN6) and doubled (2x; SN4 and SN5) atmospheric CO_2 concentrations.

	Mean	Std.	Min.	Max.	SNX/SN6*
Canola					
SN6	213	59	64	315	
SN5	274	64	93	378	1.37 (0.8-2.95)
SN4	300	51	128	378	1.49 (0.92-2.72)
Spring wheat					
SN6	189	35	100	287	
SN5	235	41	125	350	1.25 (0.98-1.84)
SN4	238	43	139	351	1.27 (1.02-1.93)
Winter wheat					
SN6	210	38	115	327	
SN5	272	70	126	515	1.32 (0.76-2.83)
SN4	271	57	152	458	1.33 (0.81-2.90)
Corn					
SN6	312	64	197	437	
SN5	570	178	193	856	1.11 (0.94-1.32)
SN4	673	131	235	875	1.77 (1.15-2.82)

*: Average and range of yield ratio.

Table VI-3c. Estimated irrigated crop yields (g/m^2) averaged over the weather grid points across Alberta for historical (1x; SN6) and doubled (2x; SN4 and SN5) atmospheric CO_2 concentrations.

	Mean	Std.	Min.	Max.	SNX/SN6*
Canola					
SN6	273	54	79	340	
SN5	359	32	217	415	1.39 (1.07-2.77)
SN4	363	31	210	413	1.40 (1.09-2.77)
Spring wheat					
SN6	366	32	188	405	
SN5	422	17	368	466	1.16 (1.06-2.01)
SN4	414	16	362	451	1.14 (1.05-1.92)
Corn					
SN6	671	19	635	699	
SN5	764	57	630	868	1.02 (0.97-1.09)
SN4	781	59	649	889	1.04 (1.00-1.11)

*: Average and range of yield ratio.

Table VI-4a: Dryland canola yield (g/m^2) averaged by Alberta Crop Reporting Districts for historical (1x; SN6) and doubled (2x; SN4 and SN5) atmospheric CO_2 concentrations.

		Crop reporting Districts	SN6	SN5	SN4	SN5/SN6	SN4/SN6
1	CD1	MedicineHat/Foremost	122	149	249	1.22	2.04
2	CD2	Lethbridge/Brooks	138	165	263	1.20	1.90
3	CD3	Claresholm/Cardston	162	256	282	1.58	1.74
4	CD4	Hanna/Empress	137	147	249	1.8	1.82
5	CD5	Drummheller/Vulcan	192	225	283	1.17	1.47
6	CD6	Calgary/Olds	180	289	286	1.60	1.59
7	CD7	Stettler/Wainwright	244	260	280	1.06	1.14
8	CD8	RedDeer	219	289	282	1.32	1.29
9	CD9	RockyMountain-region	122	250	240	2.05	1.96
10	CD10	Camrose/Vermillion	259	283	285	1.09	1.10
11	CD11	Edmonton	254	292	284	1.15	1.12
12	CD12	LacLaBiche/StPaul	230	265	258	1.15	1.12
13	CD13	Barrheah/Athabasca	229	280	266	1.22	1.16
14	CD14	Edmonton-West	162	277	251	1.71	1.55
15	CD15A	NorthPeace	210	265	253	1.26	1.20
16	CD15B	SouthPeace	207	278	264	1.34	1.28

Table VI-4b: Dryland spring wheat yields (g/m^2) averaged by Alberta Crop Reporting Districts for historical (1x; SN6) and doubled (2x; SN4 and SN5) atmospheric CO_2 concentrations.

		Crop Reporting District	SN6	SN5	SN4	SN5/SN6	SN4/SN6
1	CD1	MedicineHat/Foremost	104	140	173	1.34	1.66
2	CD2	Lethbridge/Brooks	109	145	165	1.33	1.51
3	CD3	Claresholm/Cardston	128	175	176	1.36	1.37
4	CD4	Hanna/Empress	105	128	157	1.22	1.49
5	CD5	Drummheller/Vulcan	129	168	178	1.30	1.38
6	CD6	Calgary/Olds	129	178	180	1.38	1.39
7	CD7	Stettler/Wainwright	137	172	179	1.25	1.30
8	CD8	RedDeer	131	167	169	1.27	1.28
9	CD9	RockyMountain-region	105	148	148	1.41	1.41
10	CD10	Camrose/Vermilion	149	191	194	1.29	1.30
11	CD11	Edmonton	140	173	175	1.24	1.25
12	CD12	LacLaBiche/StPaul	124	147	150	1.18	1.21
13	CD13	Barrheah/Athabasca	125	149	152	1.19	1.21
14	CD14	Edmonton-West	117	147	147	1.25	1.26
15	CD15A	NorthPeace	125	150	153	1.20	1.23
16	CD15B	SouthPeace	126	155	155	1.22	1.23

Table VI-4c: Dryland corn yields (g/m^2) averaged by Alberta Crop Reporting Districts for historical (1x; SN6) and doubled (2x; SN4 and SN5) atmospheric CO_2 concentrations. 0 represents areas without sufficient heat for corn to growth under current climate.

		Crop reporting Districts	SN6	SN5	SN4	SN5/SN6	SN4/SN6
1	CD1	MedicineHat/Foremost	170	229	412	1.34	2.42
2	CD2	Lethbridge/Brooks	204	258	426	1.27	2.09
3	CD3	Claresholm/Cardston	0	410	536	0	0
4	CD4	Hanna/Empress	183	230	392	1.25	2.14
5	CD5	Drummheller/Vulcan	230	339	537	1.47	2.34
6	CD6	Calgary/Olds	0	481	651	0	0
7	CD7	Stettler/Wainwright	0	397	626	0	0
8	CD8	RedDeer	0	646	787	0	0
9	CD9	RockyMountain-region	0	649	741	0	0
10	CD10	Camrose/Vermillion	0	489	724	0	0
11	CD11	Edmonton	0	651	808	0	0
12	CD12	LacLaBiche/StPaul	0	637	793	0	0
13	CD13	Barrheah/Athabasca	0	706	827	0	0
14	CD14	Edmonton-West	0	750	797	0	0
16	CD15B	SouthPeace	0	688	753	0	0

Table VI-4d: Dryland crested wheatgrass yields (g/m^2) averaged by Alberta Crop Reporting Districts for historical (1x; SN6) and doubled (2x; SN4 and SN5) atmospheric CO_2 concentrations.

		Crop reporting Districts	SN6	SN5	SN4	SN5/SN6	SN4/SN6
1	CD1	MedicineHat/Foremost	237	410	422	1.73	1.78
2	CD2	Lethbridge/Brooks	333	462	432	1.39	1.30
3	CD3	Claresholm/Cardston	439	578	505	1.32	1.15
4	CD4	Hanna/Empress	209	253	310	1.21	1.48
5	CD5	Drummheller/Vulcan	375	431	440	1.15	1.17
6	CD6	Calgary/Olds	439	703	700	1.60	1.60
7	CD7	Stettler/Wainwright	350	433	517	1.24	1.48
8	CD8	RedDeer	466	760	791	1.63	1.70
9	CD9	RockyMountain-region	313	756	739	2.41	2.36
10	CD10	Camrose/Vermilion	416	488	594	1.17	1.43
11	CD11	Edmonton	500	683	741	1.37	1.48
12	CD12	LacLaBiche/StPaul	424	486	579	1.15	1.36
13	CD13	Barrheah/Athabasca	461	697	762	1.51	1.65
14	CD14	Edmonton-West	394	848	834	2.15	2.11
15	CD15A	NorthPeace	382	379	425	0.99	1.11
16	CD15B	SouthPeace	425	596	623	1.40	1.47

Table VI-5a: Fallow-canola rotation yields (g/m^2) averaged by Alberta Crop Reporting Districts for historical (1x; SN6) and doubled (2x; SN4 and SN5) atmospheric CO_2 concentrations.

	Crop Reporting District		SN6	SN5	SN4	SN5/SN6	SN4/SN6
1	CD1	MedicineHat/Foremost	163	195	266	1.20	1.63
2	CD2	Lethbridge/Brooks	170	203	258	1.20	1.52
3	CD3	Claresholm/Cardston	162	270	294	1.67	1.82
4	CD4	Hanna/Empress	167	175	245	1.05	1.46
5	CD5	Drummheller/Vulcan	213	245	299	1.15	1.41
6	CD6	Calgary/Olds	184	297	306	1.61	1.66
7	CD7	Stettler/Wainwright	252	252	294	1.00	1.17
8	CD8	RedDeer	235	324	339	1.38	1.44
9	CD9	RockyMountain-region	134	284	266	2.12	1.98
10	CD10	Camrose/Vermilion	268	273	304	1.02	1.13
11	CD11	Edmonton	284	319	334	1.12	1.17
12	CD12	LacLaBiche/StPaul	247	281	299	1.14	1.21
13	CD13	Barrhead/Athabasca	258	324	339	1.26	1.32
14	CD14	Edmonton-West	180	342	327	1.90	1.82
15	CD15A	NorthPeace	211	280	288	1.33	1.36
16	CD15B	SouthPeace	219	317	326	1.45	1.49

Table VI-5b: Fallow-spring wheat rotation yields (g/m^2) averaged by Alberta Crop Reporting Districts for historical (1x; SN6) and doubled (2x; SN4 and SN5) atmospheric CO_2 concentrations.

		Crop Reporting District	SN6	SN5	SN4	SN5/SN6	SN4/SN6
1	CD1	MedicineHat/Foremost	170	215	264	1.26	1.55
2	CD2	Lethbridge/Brooks	166	209	239	1.26	1.45
3	CD3	Claresholm/Cardston	174	245	244	1.40	1.40
4	CD4	Hanna/Empress	162	187	226	1.16	1.39
5	CD5	Drummheller/Vulcan	200	249	267	1.24	1.33
6	CD6	Calgary/Olds	200	269	271	1.35	1.35
7	CD7	Stettler/Wainwright	216	256	263	1.18	1.22
8	CD8	RedDeer	202	253	246	1.25	1.22
9	CD9	RockyMountain-region	152	215	198	1.42	1.31
10	CD10	Camrose/Vermilion	238	286	288	1.20	1.21
11	CD11	Edmonton	216	256	248	1.19	1.15
12	CD12	LacLaBiche/StPaul	184	217	212	1.18	1.15
13	CD13	Barrhead/Athabasca	183	218	208	1.19	1.14
14	CD14	Edmonton-West	168	212	194	1.26	1.16
15	CD15A	NorthPeace	190	231	224	1.21	1.18
16	CD15B	SouthPeace	187	228	216	1.22	1.16

Table VI-5c: Fallow-winter wheat rotation yields (g/m^2) averaged by Alberta Crop Reporting Districts for historical (1x; SN6) and doubled (2x; SN4 and SN5) atmospheric CO_2 concentrations.

		Crop Reporting District	SN6	SN5	SN4	SN5/SN6	SN4/SN6
1	CD1	MedicineHat/Foremost	180	211	238	1.17	1.32
2	CD2	Lethbridge/Brooks	206	221	229	1.07	1.11
3	CD3	Claresholm/Cardston	202	237	238	1.17	1.18
4	CD4	Hanna/Empress	161	194	249	1.20	1.55
5	CD5	Drummheller/Vulcan	208	230	238	1.10	1.14
6	CD6	Calgary/Olds	236	264	257	1.12	1.09
7	CD7	Stettler/Wainwright	225	248	243	1.10	1.08
8	CD8	RedDeer	220	273	282	1.24	1.28
9	CD9	RockyMountain-region	192	311	295	1.62	1.54
10	CD10	Camrose/Vermilion	254	288	288	1.13	1.13
11	CD11	Edmonton	231	281	291	1.22	1.26
12	CD12	LacLaBiche/StPaul	200	296	290	1.48	1.45
13	CD13	Barrhead/Athabasca	209	346	309	1.66	1.48
14	CD14	Edmonton-West	215	336	309	1.57	1.44
15	CD15A	NorthPeace	200	246	240	1.23	1.20
16	CD15B	SouthPeace	212	311	284	1.46	1.34

Table VI-5d: Fallow-corn rotation yields (g/m^2) averaged by Alberta Crop Reporting Districts for historical (1x; SN6) and doubled (2x; SN4 and SN5) atmospheric CO_2 concentrations. 0 represents areas without sufficient heat for corn to growth under current climate.

		Crop Reporting District	SN6	SN5	SN4	SN5/SN6	SN4/SN6
1	CD1	MedicineHat/Foremost	298	373	575	1.25	1.93
2	CD2	Lethbridge/Brooks	337	379	543	1.13	1.61
3	CD3	Claresholm/Cardston	0	476	559	0	0
4	CD4	Hanna/Empress	283	323	502	1.14	1.77
5	CD5	Drummheller/Vulcan	368	477	617	1.30	1.68
6	CD6	Calgary/Olds	0	602	690	0	0
7	CD7	Stettler/Wainwright	0	532	643	0	0
8	CD8	RedDeer	0	733	799	0	0
9	CD9	RockyMountain-region	0	698	748	0	0
10	CD10	Camrose/Vermilion	0	614	712	0	0
11	CD11	Edmonton	0	731	799	0	0
12	CD12	LacLaBiche/StPaul	0	714	778	0	0
13	CD13	Barrheah/Athabasca	0	766	815	0	0
14	CD14	Edmonton-West	0	773	795	0	0
16	CD15B	SouthPeace	0	714	748	0	0

Table VI-6a: Irrigated canola yields (g/m^2) averaged by Alberta Crop Reporting Districts for historical (1x; SN6) and doubled (2x; SN4 and SN5) atmospheric CO_2 concentrations.

		Crop Reporting District	SN6	SN5	SN4	SN5/SN6	SN4/SN6
1	CD1	MedicineHat/Foremost	293	336	341	1.15	1.16
2	CD2	Lethbridge/Brooks	297	338	347	1.14	1.17
3	CD3	Claresholm/Cardston	256	375	383	1.46	1.50
4	CD4	Hanna/Empress	298	337	342	1.13	1.15
5	CD5	Drummheller/Vulcan	300	349	359	1.17	1.20
6	CD6	Calgary/Olds	233	368	372	1.58	1.60
7	CD7	Stettler/Wainwright	310	351	360	1.13	1.16
8	CD8	RedDeer	265	378	382	1.42	1.44
9	CD9	RockyMountain-region	162	332	331	2.05	2.04
10	CD10	Camrose/Vermilion	312	355	364	1.14	1.17
11	CD11	Edmonton	312	385	389	1.23	1.25
12	CD12	LacLaBiche/StPaul	282	357	361	1.27	1.28
13	CD13	Barrheah/Athabasca	283	386	385	1.36	1.36
14	CD14	Edmonton-West	206	380	372	1.85	1.81
15	CD15A	NorthPeace	262	340	342	1.30	1.30
16	CD15B	SouthPeace	256	371	370	1.45	1.44

Table VI-6b: Irrigated spring wheat yields (g/m^2) averaged by Alberta Crop Reporting Districts for historical (1x; SN6) and doubled (2x; SN4 and SN5) atmospheric CO_2 concentrations.

		Crop Reporting District	SN6	SN5	SN4	SN5/SN6	SN4/SN6
1	CD1	MedicineHat/Foremost	362	414	417	1.14	1.15
2	CD2	Lethbridge/Brooks	375	416	415	1.11	1.11
3	CD3	Claresholm/Cardston	373	435	416	1.17	1.12
4	CD4	Hanna/Empress	362	411	411	1.14	1.14
5	CD5	Drummheller/Vulcan	380	428	423	1.13	1.11
6	CD6	Calgary/Olds	356	436	418	1.23	1.17
7	CD7	Stettler/Wainwright	383	433	429	1.13	1.12
8	CD8	RedDeer	372	434	417	1.17	1.12
9	CD9	RockyMountain-region	304	413	398	1.36	1.31
10	CD10	Camrose/Vermilion	386	432	430	1.12	1.11
11	CD11	Edmonton	385	430	417	1.12	1.09
12	CD12	LacLaBiche/StPaul	365	409	402	1.12	1.10
13	CD13	Barrheah/Athabasca	372	417	405	1.12	1.09
14	CD14	Edmonton-West	346	415	403	1.20	1.17
15	CD15A	NorthPeace	354	405	402	1.14	1.13
16	CD15B	SouthPeace	363	418	408	1.15	1.12

Table VI-6c: Irrigated corn yields (g/m^2) averaged by Alberta Crop Reporting Districts for historical (1x; SN6) and doubled (2x; SN4 and SN5) atmospheric CO_2 concentrations. 0 represents areas without sufficient heat for corn to growth under current climate.

		Crop Reporting District	SN6	SN5	SN4	SN5/SN6	SN4/SN6
1	CD1	MedicineHat/Foremost	664	684	696	1.03	1.05
2	CD2	Lethbridge/Brooks	681	713	725	1.05	1.06
3	CD3	Claresholm/Cardston	0	788	795	0	0
4	CD4	Hanna/Empress	662	698	712	1.05	1.08
5	CD5	Drummheller/Vulcan	682	735	751	1.08	1.10
6	CD6	Calgary/Olds	0	790	804	0	0
7	CD7	Stettler/Wainwright	0	747	768	0	0
8	CD8	RedDeer	0	809	831	0	0
9	CD9	RockyMountain-region	0	804	821	0	0
10	CD10	Camrose/Vermilion	0	763	791	0	0
11	CD11	Edmonton	0	814	840	0	0
12	CD12	LacLaBiche/StPaul	0	802	828	0	0
13	CD13	Barrheah/Athabasca	0	827	851	0	0
14	CD14	Edmonton-West	0	811	823	0	0
16	CD15B	SouthPeace	0	792	802	0	0

VII. CONCLUSIONS

Two climate scenarios predicting 4°C increase in temperature (SN5) and °4 C and 28% increase in temperature and precipitation (SN4) were used to investigate climate impact on agriculture. The results of simulation showed profound effect on agroclimatic indices and crop yields.

Higher corn heat unit and growing degree day than current will be expected with the direct consequence that the capacity for growing crops that now exists in the south will be relocated north. Also will be expected seeding dates that are about 3 weeks earlier than the current dates, a frost free season that is about 40 days longer, shorter growth duration, earlier regrowth of perennials and winter wheat in the spring and less likelihood of winter kill of winter annual crops. As a result, average yields in most region actually increase under the two climate scenarios. Dryland crops seeded to stubble will benefit the most when precipitation was increased especially for corn while irrigated crops with higher yields will benefit less.

Agricultural adaptation to changing climate will occur in several ways. Field works will start earlier and more irrigation will be performed to alleviate yield loss especially for canola. There will likely be substantial shifts toward winter wheat with the most adversed case of climate change as the early regrowth and reduced risk of winter kill will make this more profitable than spring wheat. The reverse is true when precipitation level is higher than current. The potential for canola may diminish in the south due to excessive heat but this should be offset by the improved capability of growing warm season crops such as corn and beans. It may be possible to grow winter canola. Another important shift is likely to be a trend toward less area seeded to cool season crops such as the small grains and more area devoted to warm season crops such as corn. Also, irrigation practices can help to alleviate yield loss especially for canola.

However, these results should be tempered by critical uncertainties related to the physiological response of crops under the elevated CO_2 environment and the GCM climate predictions particularly with respect to precipitation.

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APPENDIX A

Command files and program codes

Appendix A-IV.1: Generic command file; example to execute corn heat program for SN5.

```
$SET VERIFY =(PROCEDURE)
$ SET DEFAULT [CS.major.nchristy.outmaps]
$ior chu5
$for grdname
$link chu5,grdname
$run chu5
```

Appendix A-IV.2: Subroutine linking weather grid code to geographic coordinates

GRDNAME.FOR

```
C*************************************************************
      SUBROUTINE GRIDNAM(FILEIN,XLAT,XLONG)
C*************************************************************
C     RETURNS THE GEOGRAPHIC COORDINATES (LAT,LONG) OF A
C       A GIVEN GRID POINT NAME
C*************************************************************
      CHARACTER FILEN*4, FILEIN*15
      INTEGER LAT, LONG
      REAL XLAT,XLONG


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ELSEIF (FILEN.EQ.'CC39') THEN
 LAT =5299
 LONG =11475
ELSEIF (FILEN.EQ.'CC41') THEN
```

```
 LAT =5340
 LONG =11775
ELSEIF (FILEN.EQ.'CC43') THEN
 LAT =5340
 LONG =11700
ELSEIF (FILEN.EQ.'CC45') THEN
 LAT =5340
 LONG =11625
ELSEIF (FILEN.EQ.'CC47') THEN
 LAT =5340
 LONG =11550
ELSEIF (FILEN.EQ.'CC49') THEN
 LAT =5340
 LONG =11475
ELSEIF (FILEN.EQ.'CC51') THEN
 LAT =5381
 LONG =11775
ELSEIF (FILEN.EQ.'CC53') THEN
 LAT =5381
 LONG =11700
ELSEIF (FILEN.EQ.'CC55') THEN
 LAT =5381
 LONG =11625
ELSEIF (FILEN.EQ.'CC57') THEN
 LAT =5381
 LONG =11550
ELSEIF (FILEN.EQ.'CC59') THEN
 LAT =5381
 LONG =11475
ELSEIF (FILEN.EQ.'CC65') THEN
 LAT =5422
 LONG =11625
ELSEIF (FILEN.EQ.'CC67') THEN
 LAT =5422
 LONG =11550
ELSEIF (FILEN.EQ.'CC69') THEN
 LAT =5422
 LONG =11475
ELSEIF (FILEN.EQ.'CC77') THEN
 LAT =5463
 LONG =11550
ELSEIF (FILEN.EQ.'CC79') THEN
 LAT =5463
 LONG =11475
ELSEIF (FILEN.EQ.'CC87') THEN
 LAT =5505
 LONG =11550
ELSEIF (FILEN.EQ.'CC89') THEN
 LAT =5505
 LONG =11475
ELSEIF (FILEN.EQ.'CC97') THEN
 LAT =5546
 LONG =11550
ELSEIF (FILEN.EQ.'CC99') THEN
 LAT =5546
 LONG =11475
ELSEIF (FILEN.EQ.'CD11') THEN
 LAT =5216
 LONG =11400
ELSEIF (FILEN.EQ.'CD13') THEN
 LAT =5216
 LONG =11325
ELSEIF (FILEN.EQ.'CD15') THEN
 LAT =5216
 LONG =11250
ELSEIF (FILEN.EQ.'CD17') THEN
 LAT =5216
 LONG =11175
ELSEIF (FILEN.EQ.'CD19') THEN
 LAT =5216
 LONG =11100
ELSEIF (FILEN.EQ.'CD21') THEN
 LAT =5257
 LONG =11400
ELSEIF (FILEN.EQ.'CD23') THEN
 LAT =5257
 LONG =11325
ELSEIF (FILEN.EQ.'CD25') THEN
 LAT =5257
 LONG =11250
ELSEIF (FILEN.EQ.'CD27') THEN
 LAT =5257
 LONG =11175
ELSEIF (FILEN.EQ.'CD29') THEN
 LAT =5257
 LONG =11100
ELSEIF (FILEN.EQ.'CD31') THEN
 LAT =5299
 LONG =11400
ELSEIF (FILEN.EQ.'CD33') THEN
 LAT =5299
 LONG =11325
ELSEIF (FILEN.EQ.'CD35') THEN
 LAT =5299
 LONG =11250
ELSEIF (FILEN.EQ.'CD37') THEN
 LAT =5299
 LONG =11175
ELSEIF (FILEN.EQ.'CD39') THEN
 LAT =5299
 LONG =11100
ELSEIF (FILEN.EQ.'CD41') THEN
 LAT =5340
 LONG =11400
ELSEIF (FILEN.EQ.'CD43') THEN
 LAT =5340
 LONG =11325
ELSEIF (FILEN.EQ.'CD45') THEN
 LAT =5340
 LONG =11250
ELSEIF (FILEN.EQ.'CD47') THEN
 LAT =5340
 LONG =11175
ELSEIF (FILEN.EQ.'CD49') THEN
 LAT =5340
 LONG =11100
ELSEIF (FILEN.EQ.'CD51') THEN
 LAT =5381
 LONG =11400
ELSEIF (FILEN.EQ.'CD53') THEN
 LAT =5381
 LONG =11325
ELSEIF (FILEN.EQ.'CD55') THEN
 LAT =5381
 LONG =11250
ELSEIF (FILEN.EQ.'CD57') THEN
 LAT =5381
 LONG =11175
ELSEIF (FILEN.EQ.'CD59') THEN
 LAT =5381
 LONG =11100
ELSEIF (FILEN.EQ.'CD61') THEN
 LAT =5422
 LONG =11400
ELSEIF (FILEN.EQ.'CD63') THEN
 LAT =5422
```

```
 LONG =11325
ELSEIF (FILEN.EQ.'CD67') THEN
 LAT =5422
 LONG =11175
ELSEIF (FILEN.EQ.'CD69') THEN
 LAT =5422
 LONG =11100
ELSEIF (FILEN.EQ.'CD71') THEN
 LAT =5463
 LONG =11400
ELSEIF (FILEN.EQ.'CD73') THEN
 LAT =5463
 LONG =11325
ELSEIF (FILEN.EQ.'CD77') THEN
 LAT =5463
 LONG =11175
ELSEIF (FILEN.EQ.'CD79') THEN
 LAT =5463
 LONG =11100
ELSEIF (FILEN.EQ.'CD81') THEN
 LAT =5505
 LONG =11400
ELSEIF (FILEN.EQ.'CD83') THEN
 LAT =5505
 LONG =11325
ELSEIF (FILEN.EQ.'CD85') THEN
 LAT =5505
 LONG =11250
ELSEIF (FILEN.EQ.'CD91') THEN
 LAT =5546
 LONG =11400
ELSEIF (FILEN.EQ.'CE11') THEN
 LAT =5216
 LONG =11025
ELSEIF (FILEN.EQ.'CE21') THEN
 LAT =5257
 LONG =11025
ELSEIF (FILEN.EQ.'CE31') THEN
 LAT =5299
 LONG =11025
ELSEIF (FILEN.EQ.'CE41') THEN
 LAT =5340
 LONG =11025
ELSEIF (FILEN.EQ.'CE51') THEN
 LAT =5381
 LONG =11025
ELSEIF (FILEN.EQ.'CE61') THEN
 LAT =5422
 LONG =11025
ELSEIF (FILEN.EQ.'CE71') THEN
 LAT =5463
 LONG =11025
ELSEIF (FILEN.EQ.'DB15') THEN
 LAT =5587
 LONG =12000
ELSEIF (FILEN.EQ.'DB17') THEN
 LAT =5587
 LONG =11925
ELSEIF (FILEN.EQ.'DB19') THEN
 LAT =5587
 LONG =11850
ELSEIF (FILEN.EQ.'DB25') THEN
 LAT =5628
 LONG =12000
ELSEIF (FILEN.EQ.'DB27') THEN
 LAT =5628
 LONG =11925
ELSEIF (FILEN.EQ.'DB29') THEN
 LAT =5628
 LONG =11850
ELSEIF (FILEN.EQ.'DC11') THEN
 LAT =5587
 LONG =11775
ELSEIF (FILEN.EQ.'DC13') THEN
 LAT =5587
 LONG =11700
ELSEIF (FILEN.EQ.'DC19') THEN
 LAT =5587
 LONG =11475
ELSEIF (FILEN.EQ.'DC21') THEN
 LAT =5628
 LONG =11775
ELSEIF (FILEN.EQ.'DC23') THEN
 LAT =5628
 LONG =11700
ELSEIF (FILEN.EQ.'DC31') THEN
 LAT =5670
 LONG =11775
ELSEIF (FILEN.EQ.'DC33') THEN
 LAT =5670
 LONG =11700
ELSEIF (FILEN.EQ.'DC51') THEN
 LAT =5752
 LONG =11775
ELSEIF (FILEN.EQ.'DC71') THEN
 LAT =5834
 LONG =11775
ELSEIF (FILEN.EQ.'DC73') THEN
 LAT =5834
 LONG =11700
ELSEIF (FILEN.EQ.'DC75') THEN
 LAT =5834
 LONG =11625
ELSEIF (FILEN.EQ.'DC85') THEN
 LAT =5875
 LONG =11625
ELSEIF (FILEN.EQ.'DD27') THEN
 LAT =5628
 LONG =11175
ELSEIF (FILEN.EQ.'DD29') THEN
 LAT =5628
 LONG =11100
ELSEIF (FILEN.EQ.'DD37') THEN
 LAT =5670
 LONG =11175
ELSEIF (FILEN.EQ.'DD39') THEN
 LAT =5670
 LONG =11100
ELSEIF (FILEN.EQ.'DD47') THEN
 LAT =5711
 LONG =11175
ELSEIF (FILEN.EQ.'DD49') THEN
 LAT =5711
 LONG =11100
ELSEIF (FILEN.EQ.'DE31') THEN
 LAT =5670
 LONG =11025
ELSE
 LAT=0
 LONG=0

XLAT=LAT/100.
XLONG=LONG/100.

RETURN
END
```

Appendix A-IV.3: Generic Fortran program to calculated thermal time.

Corn Heats Units

```
C*****************************************************************
C task: To generate corn heat unit for each grid point
C  1: read the grid point file name: SNx_CCxx.MET
C     SNx: Scenario number;
C     CCxx:character allocated to the grid point
C  2: write all the above information in a file
C*****************************************************************

      CHARACTER OUTDIR*27,FILENAME*15,WEAT_DIR*20
      REAL XILAT,XILNG,MEAN_CHU,STD

      OUTDIR='[cs.major.nchristy.outmaps]'
      WEAT_DIR='$42$DUC3:[BARR.SN6B]'
      OPEN(12,FILE='files6.tmp',STATUS='OLD')

      OPEN(13,FILE=OUTDIR//'chu6.LL',
     & CARRIAGECONTROL='LIST',STATUS='NEW')

      NREC= 5000 !number of records (STATION) in the sas job file

       DO I=1,NREC
        READ(12,505,end=100) FILENAME
        CALL CRNHEAT(WEAT_DIR,FILENAME,MEAN_CHU,STD)
        CALL GRIDNAM(FILENAME,XILAT,XILNG)
        WRITE(13,600)FILENAME,XILAT,XILNG,MEAN_CHU,STD
       ENDDO

100   CLOSE(12)

505   FORMAT(A15)
600   FORMAT(2X,A8,3X,F5.2,2X,F6.2,2(2X,F6.1))

      STOP
      END
C*************************************************
C  Weather file format for EPIC input file
      SUBROUTINE CRNHEAT(dir,filein,mean_chu,STD)
C*************************************************

      character filein*15,dir*20
      real chu(30),std
      real rad,tmax(370),tmin(370),rain,snow,tprec
      real std_chu,sum_chu,mean_chu,tmx,tmn
      real hu,x,y
      integer idim(12)

      data idim/31,28,31,30,31,30,31,31,30,31,30,31/

      open(9,file=dir//filein,status='old')

      do j=1,30  !number of year
        iyr=1959+j ! starting from 1960 to 1989
        idoy=0
        do i=1,12
          if (mod(iyr,4).eq.0) then
             idim(2)=29
          else
             idim(2)=28
          endif
```

```
      id=idim(i)

      do k=1,id
         read(9,*,end=100) rad,tmx,tmn,rain,snow,tprec
         idoy=idoy+1
         tmax(idoy)=tmx
         tmin(idoy)=tmn
       enddo !day
     enddo !month

     hu=0.0

C********** Corn Heat unit **********

     do i=1,idoy
       if(i.lt.135) goto 10
       Y=3.33*(tmax(i) - 10.0) - 0.084*(tmax(i) - 10.0)**2
       X=1.8*(tmin(i) - 4.4)
       if(y.lt.0.0) y=0.0
       if(x.lt.0.0) x=0.0
       hu=hu+(y+x)/2.
       if(i.gt.182.and.tmin(i).le.-2.0) goto 30
10     enddo
30     chu(j)=hu
   enddo ! year

C**************************************************

   sum_chu = 0.0

   do k=1,30
     sum_chu=sum_chu+chu(k)
   enddo
   mean_chu=sum_chu/30.

   std_chu = 0.0

   do k=1,30
     std_chu=std_chu+(chu(k)-mean_chu)**2
   enddo

   std=sqrt(std_chu/30.)

100  close(9)

   return
   END
```

Growing Degree Days with a base of 0° C

```
     do i=1,idoy
       if(i.lt.135) goto 10
       y=tmax(i)
       x=tmin(i)
       if(y.lt.0.0) y=0.0
       if(x.lt.0.0) x=0.0
       hu=hu+(y+x)/2.
       if(i.gt.182.and.tmin(i).le.-2.0) goto 30
10     enddo
30     gdd(j)=hu
   enddo ! year
```

Growing Degree Days with a base of 5° C

```
     do i=1,idoy
```

```
        if(i.lt.135) goto 10
        y=tmax(i)
        x=tmin(i)
        if(y.lt.5.0) y=5.0
        if(x.lt.5.0) x=5.0
        hu=hu+(y+x)/2.-5.0
        if(i.gt.182.and.tmin(i).le.-2.0) goto 30
10      enddo
30      gdd(j)=hu
      enddo ! year
```

Growing Degree Days with a base of 8° C

```
      do i=1,idoy
        if(i.lt.135) goto 10
        y=tmax(i)
        x=tmin(i)
        if(y.lt.8.0) y=8.0
        if(x.lt.8.0) x=8.0
        hu=hu+(y+x)/2.-8.
        if(i.gt.182.and.tmin(i).le.-2.0) goto 30
10      enddo
30      gdd(j)=hu
      enddo ! year
```

Growing Degree Days with a base of 10° C

```
      do i=1,idoy
        if(i.lt.135) goto 10
        y=tmax(i)
        x=tmin(i)
        if(y.lt.10.0) y=10.0
        if(x.lt.10.0) x=10.0
        hu=hu+(y+x)/2.-10.
        if(i.gt.182.and.tmin(i).le.-2.0) goto 30
10      enddo
30      gdd(j)=hu
      enddo ! year
```

Frost Free Days

```
      do i=1,idoy
        y=tmax(i)
        x=tmin(i)
        if(i.lt.182.and.x.lt.-2) start=i
        if(i.gt.182.and.x.lt.-2) then
          end=i
          hu=end-start
          goto 30
10      enddo
30      gdd(j)=hu
      enddo ! year
```

Heating Degree days

```
      do i=1,idoy
        y=tmax(i)
        x=tmin(i)
        if(y.gt.18.0) y=18.0
        if(x.gt.18.0) x=18.0
        hu=hu+18-(y+x)/2.
10      enddo
```

```
      gdd(j)=hu
    enddo ! year
```

Spring Regrowth (average spring temperature of 11 C)

```
      do i=1,idoy
        if (i.lt.10) goto 10
        y=tmax(i)
        x=tmin(i)
        total=0
       do m=1,10
        kounter=i-m-1
        total=total+(tmax(kounter)+tmin(kounter))/2
       enddo
        avg=total/10.
        if (avg.gt.11.0) go to 30
10     enddo
30     gdd(j)=i
```

Critical Fall Harvest date (average fall temperature of 11 C)

```
      do i=1,idoy
        if (i.lt.182) goto 10
        y=tmax(i)
        x=tmin(i)
        total=0
       do m=1,10
        kounter=i-m-1
        total=total+(tmax(kounter)+tmin(kounter))/2
       enddo
        avg=total/10.
        if(avg.lt.11.0) goto 30
10     enddo
30     gdd(j)=i
```

APPENDIX A-IV.4: SAS command file to calculate correlation coefficients and format output parameters by weather grid points.

```
OPTIONS LS=80;

FILENAME grid '[CS.MAJOR.nchristy.outmaps]grid.out';
FILENAME chu5 '[CS.MAJOR.nchristy.outmaps]chu5.ll';
FILENAME chu6 '[CS.MAJOR.nchristy.outmaps]chu6.ll';
FILENAME gdd0_5 '[CS.MAJOR.nchristy.outmaps]gdd0_5.ll';
FILENAME gdd0_6 '[CS.MAJOR.nchristy.outmaps]gdd0_6.ll';
FILENAME gdd5_5 '[CS.MAJOR.nchristy.outmaps]gdd5_5.ll';
FILENAME gdd5_6 '[CS.MAJOR.nchristy.outmaps]gdd5_6.ll';
FILENAME gdd8_5 '[CS.MAJOR.nchristy.outmaps]gdd8_5.ll';
FILENAME gdd8_6 '[CS.MAJOR.nchristy.outmaps]gdd8_6.ll';
FILENAME gdd10_5 '[CS.MAJOR.nchristy.outmaps]gdd10_5.ll';
FILENAME gdd10_6 '[CS.MAJOR.nchristy.outmaps]gdd10_6.ll';
FILENAME hdd18_5 '[CS.MAJOR.nchristy.outmaps]hdd18_5.ll';
FILENAME hdd18_6 '[CS.MAJOR.nchristy.outmaps]hdd18_6.ll';
FILENAME ffd_5 '[CS.MAJOR.nchristy.outmaps]ffd_5.ll';
FILENAME ffd_6 '[CS.MAJOR.nchristy.outmaps]ffd_6.ll';
FILENAME engrow_5 '[CS.MAJOR.nchristy.outmaps]engrow_5.ll';
FILENAME engrow_6 '[CS.MAJOR.nchristy.outmaps]engrow_6.ll';
FILENAME regrow_5 '[CS.MAJOR.nchristy.outmaps]regrow_5.ll';
FILENAME regrow_6 '[CS.MAJOR.nchristy.outmaps]regrow_6.ll';

DATA chu5; INFILE chu5; INPUT name $ 7-11 long lat chu std_chu; scenario=2;
long=long*-1;
proc sort; by name scenario;
DATA chu6; INFILE chu6; INPUT name $ 7-11 long lat chu std_chu; scenario=1;
long=long*-1;
proc sort; by name scenario;
proc gcontour; by scenario; plot long*lat=chu/levels=800 to 3400 by 400;

DATA gdd0_5; INFILE gdd0_5; INPUT name $ 7-11 long lat gdd0 s_gdd0; scenario=2;
proc sort; by name scenario;
DATA gdd0_6; INFILE gdd0_6; INPUT name $ 7-11 long lat gdd0 s_gdd0; scenario=1;
proc sort; by name scenario;

DATA gdd5_5; INFILE gdd5_5; INPUT name $ 7-11 long lat gdd5 s_gdd5; scenario=2;
proc sort; by name scenario;
DATA gdd5_6; INFILE gdd5_6; INPUT name $ 7-11 long lat gdd5 s_gdd5; scenario=1;
proc sort; by name scenario;

DATA gdd8_5; INFILE gdd8_5; INPUT name $ 7-11 long lat gdd8 s_gdd8; scenario=2;
proc sort; by name scenario;
DATA gdd8_6; INFILE gdd8_6; INPUT name $ 7-11 long lat gdd8 s_gdd8; scenario=1;
proc sort; by name scenario;

DATA gdd10_5; INFILE gdd10_5; INPUT name $ 7-11 long lat gdd10 s_gdd10; scenario=2;
proc sort; by name scenario;
DATA gdd10_6; INFILE gdd10_6; INPUT name $ 7-11 long lat gdd10 s_gdd10; scenario=1;
proc sort; by name scenario;

DATA hdd18_5; INFILE hdd18_5; INPUT name $ 7-11 long lat hdd18 s_hdd18; scenario=2;
proc sort; by name scenario;
DATA hdd18_6; INFILE hdd18_6; INPUT name $ 7-11 long lat hdd18 s_hdd18; scenario=1;
proc sort; by name scenario;

DATA ffd_5; INFILE ffd_5; INPUT name $ 7-11 long lat ffd s_ffd; scenario=2;
proc sort; by name scenario;
DATA ffd_6; INFILE ffd_6; INPUT name $ 7-11 long lat ffd s_ffd; scenario=1;
proc sort; by name scenario;

DATA regrow_5; INFILE regrow_5; INPUT name $ 7-11 long lat regrow s_regrow; scenario=2;
```

```
proc sort; by name scenario;
DATA regrow_6; INFILE regrow_6; INPUT name $ 7-11 long lat regrow s_regrow; scenario=1;
proc sort; by name scenario;

DATA engrow_5; INFILE engrow_5; INPUT name $ 7-11 long lat engrow s_engrow; scenario=2;
proc sort; by name scenario;
DATA engrow_6; INFILE engrow_6; INPUT name $ 7-11 long lat engrow s_engrow; scenario=1;
proc sort; by name scenario;

data all; merge chu5 chu6 gdd0_5 gdd0_6 gdd5_5 gdd5_6 gdd8_5 gdd8_6 gdd10_5
gdd10_6 hdd18_5 hdd18_6 ffd_5 ffd_6 regrow_5 regrow_6 engrow_5 engrow_6;
by name scenario;
chuclass=int((chu+100)/200)*200;
gddclass=int((50-210+chuclass*.574)/100)*100;

proc corr; var chu gdd0 gdd5 gdd8 gdd10 hdd18 ffd regrow engrow;

proc summary; class name scenario;
var chu gdd0 gdd5 gdd8 gdd10 hdd18 ffd regrow engrow;
output out=work1 mean=; data work2; set work1; if _type_='11'b;
data _null_; set work2;
chu=int(chu); gdd0=int(gdd0); gdd5=int(gdd5); gdd8=int(gdd8);
gdd10=int(gdd10); hdd18=int(hdd18); ffd=int(ffd);
regrow=int(regrow); engrow=int(engrow);
file grid; put name scenario chu gdd0 gdd5 gdd8 gdd10 hdd18 ffd regrow engrow;


proc sort; by scenario;
proc univariate;  by scenario;
var chu gdd0 gdd5 gdd8 gdd10 hdd18 ffd regrow engrow;
```

APPENDIX A-IV.5: Creating site files

```
OPTIONS LS=80;

FILENAME grid '[CS.MAJOR.nchristy.outmaps]grid.utm';

FILENAME chu5 '[CS.MAJOR.nchristy.outmaps]chu5.ll';
FILENAME chu6 '[CS.MAJOR.nchristy.outmaps]chu6.ll';
FILENAME gdd0_5 '[CS.MAJOR.nchristy.outmaps]gdd0_5.ll';
FILENAME gdd0_6 '[CS.MAJOR.nchristy.outmaps]gdd0_6.ll';
FILENAME gdd5_5 '[CS.MAJOR.nchristy.outmaps]gdd5_5.ll';
FILENAME gdd5_6 '[CS.MAJOR.nchristy.outmaps]gdd5_6.ll';
FILENAME gdd8_5 '[CS.MAJOR.nchristy.outmaps]gdd8_5.ll';
FILENAME gdd8_6 '[CS.MAJOR.nchristy.outmaps]gdd8_6.ll';
FILENAME gdd10_5 '[CS.MAJOR.nchristy.outmaps]gdd10_5.ll';
FILENAME gdd10_6 '[CS.MAJOR.nchristy.outmaps]gdd10_6.ll';
FILENAME hdd18_5 '[CS.MAJOR.nchristy.outmaps]hdd18_5.ll';
FILENAME hdd18_6 '[CS.MAJOR.nchristy.outmaps]hdd18_6.ll';
FILENAME ffd_5 '[CS.MAJOR.nchristy.outmaps]ffd_5.ll';
FILENAME ffd_6 '[CS.MAJOR.nchristy.outmaps]ffd_6.ll';
FILENAME engrow_5 '[CS.MAJOR.nchristy.outmaps]engrow_5.ll';
FILENAME engrow_6 '[CS.MAJOR.nchristy.outmaps]engrow_6.ll';
FILENAME regrow_5 '[CS.MAJOR.nchristy.outmaps]regrow_5.ll';
FILENAME regrow_6 '[CS.MAJOR.nchristy.outmaps]regrow_6.ll';

filename pchu5 '[CS.MAJOR.nchristy.outmaps]chu5.pts';
filename pchu6 '[CS.MAJOR.nchristy.outmaps]chu6.pts';
filename pgdd0_5 '[CS.MAJOR.nchristy.outmaps]gdd0_5.pts';
filename pgdd0_6 '[CS.MAJOR.nchristy.outmaps]gdd0_6.pts';
filename pgdd5_5 '[CS.MAJOR.nchristy.outmaps]gdd5_5.pts';
filename pgdd5_6 '[CS.MAJOR.nchristy.outmaps]gdd5_6.pts';
filename pgdd8_5 '[CS.MAJOR.nchristy.outmaps]gdd8_5.pts';
filename pgdd8_6 '[CS.MAJOR.nchristy.outmaps]gdd8_6.pts';
filename pgdd10_5 '[CS.MAJOR.nchristy.outmaps]gdd10_5.pts';
filename pgdd10_6 '[CS.MAJOR.nchristy.outmaps]gdd10_6.pts';
filename phdd18_5 '[CS.MAJOR.nchristy.outmaps]hdd18_5.pts';
filename phdd18_6 '[CS.MAJOR.nchristy.outmaps]hdd18_6.pts';
filename pffd_5 '[CS.MAJOR.nchristy.outmaps]ffd_5.pts';
filename pffd_6 '[CS.MAJOR.nchristy.outmaps]ffd_6.pts';
filename pengrw_5 '[CS.MAJOR.nchristy.outmaps]engrow_5.pts';
filename pengrw_6 '[CS.MAJOR.nchristy.outmaps]engrow_6.pts';
filename pregrw_5 '[CS.MAJOR.nchristy.outmaps]regrow_5.pts';
filename pregrw_6 '[CS.MAJOR.nchristy.outmaps]regrow_6.pts';

DATA grid; INFILE grid; INPUT northing easting zone name $ ;
easting=int(easting*100)/100; northing=int(northing*100)/100;
scenario=2; proc sort; by name;

DATA chu5; INFILE chu5; INPUT name $ 7-11 lat long chu std_chu; scenario=2;
class=int((chu-700)/200); long=-long; proc sort; by name;
data chu5u; merge chu5 grid; by name;
DATA chu6; INFILE chu6; INPUT name $ 7-11 lat long chu std_chu; scenario=1;
class=int((chu-700)/200); long=-long; proc sort; by name;
data chu6u; merge chu6 grid; by name;

DATA gdd0_5; INFILE gdd0_5; INPUT name $ 7-11 lat long gdd0 s_gdd0; scenario=2;
class=int((gdd0-900)/200); long=-long; proc sort; by name;
data gdd0_5u; merge gdd0_5 grid; by name;
DATA gdd0_6; INFILE gdd0_6; INPUT name $ 7-11 lat long gdd0 s_gdd0; scenario=1;
class=int((gdd0-900)/200); long=-long; proc sort; by name;
data gdd0_6u; merge gdd0_6 grid; by name;

DATA gdd5_5; INFILE gdd5_5; INPUT name $ 7-11 lat long gdd5 s_gdd5; scenario=2;
class=int((gdd5-500)/200); long=-long; proc sort; by name;
```

```
data gdd5_5u; merge gdd5_5 grid; by name;
DATA gdd5_6; INFILE gdd5_6; INPUT name $ 7-11 lat long gdd5 s_gdd5; scenario=1;
class=int((gdd5-500)/200); long=-long; proc sort; by name;
data gdd5_6u; merge gdd5_6 grid; by name;

DATA gdd8_5; INFILE gdd8_5; INPUT name $ 7-11 lat long gdd8 s_gdd8; scenario=2;
class=int((gdd8-300)/100); long=-long; proc sort; by name;
data gdd8_5u; merge gdd8_5 grid; by name;
DATA gdd8_6; INFILE gdd8_6; INPUT name $ 7-11 lat long gdd8 s_gdd8; scenario=1;
class=int((gdd8-300)/100); long=-long; proc sort; by name;
data gdd8_6u; merge gdd8_6 grid; by name;

DATA gdd10_5; INFILE gdd10_5; INPUT name $ 7-11 lat long gdd10 s_gdd10; scenario=2;
class=int((gdd10-100)/100); long=-long; proc sort; by name;
data gdd10_5u; merge gdd10_5 grid; by name;
DATA gdd10_6; INFILE gdd10_6; INPUT name $ 7-11 lat long gdd10 s_gdd10; scenario=1;
class=int((gdd10-100)/100); long=-long; proc sort; by name;
data gdd10_6u; merge gdd10_6 grid; by name;

DATA hdd18_5; INFILE hdd18_5; INPUT name $ 7-11 lat long hdd18 s_hdd18; scenario=2;
class=int((hdd18-3000)/400); long=-long; proc sort; by name;
data hdd18_5u; merge hdd18_5 grid; by name;
DATA hdd18_6; INFILE hdd18_6; INPUT name $ 7-11 lat long hdd18 s_hdd18; scenario=1;
class=int((hdd18-3000)/400); long=-long; proc sort; by name;
data hdd18_6u; merge hdd18_6 grid; by name;

DATA ffd_5; INFILE ffd_5; INPUT name $ 7-11 lat long ffd s_ffd; scenario=2;
class=int((ffd-70)/20); long=-long; proc sort; by name;
data ffd_5u; merge ffd_5 grid; by name;
DATA ffd_6; INFILE ffd_6; INPUT name $ 7-11 lat long ffd s_ffd; scenario=1;
class=int((ffd-70)/20); long=-long; proc sort; by name;
data ffd_6u; merge ffd_6 grid; by name;

DATA regrow_5; INFILE regrow_5; INPUT name $ 7-11 lat long regrow s_regrow; scenario=2;
class=int((regrow-30)/10); long=-long; proc sort; by name;
data regrw_5u; merge regrow_5 grid; by name;
DATA regrow_6; INFILE regrow_6; INPUT name $ 7-11 lat long regrow s_regrow; scenario=1;
class=int((regrow-30)/10); long=-long; proc sort; by name;
data regrw_6u; merge regrow_6 grid; by name;

DATA engrow_5; INFILE engrow_5; INPUT name $ 7-11 lat long engrow s_engrow; scenario=2;
class=int((engrow-170)/10); long=-long; proc sort; by name;
data engrw_5u; merge engrow_5 grid; by name;
DATA engrow_6; INFILE engrow_6; INPUT name $ 7-11 lat long engrow s_engrow; scenario=1;
class=int((engrow-170)/10); long=-long; proc sort; by name;
data engrw_6u; merge engrow_6 grid; by name;


data _null_; set chu5u;
file pchu5; put @1 easting @15 northing @30 class;
data _null_; set chu6u;
file pchu6; put @1 easting @15 northing @30 class;
data _null_; set gdd0_5u;
file pgdd0_5; put @1 easting @15 northing @30 class;
data _null_; set gdd0_6u;
file pgdd0_6; put @1 easting @15 northing @30 class;
data _null_; set gdd5_5u;
file pgdd5_5; put @1 easting @15 northing @30 class;
data _null_; set gdd5_6u;
file pgdd5_6; put @1 easting @15 northing @30 class;
data _null_; set gdd8_5u;
file pgdd8_5; put @1 easting @15 northing @30 class;
data _null_; set gdd8_6u;
file pgdd8_6; put @1 easting @15 northing @30 class;
data _null_; set gdd10_5u;
file pgdd10_5; put @1 easting @15 northing @30 class;
data _null_; set gdd10_6u;
file pgdd10_6; put @1 easting @15 northing @30 class;
```

```
data _null_; set hdd18_5u;
file phdd18_5; put @1 easting @15 northing @30 class;
data _null_; set hdd18_6u;
file phdd18_6; put @1 easting @15 northing @30 class;
data _null_; set ffd_5u;
file pffd_5; put @1 easting @15 northing @30 class;
data _null_; set ffd_6u;
file pffd_6; put @1 easting @15 northing @30 class;
data _null_; set engrw_5u;
file pengrw_5; put @1 easting @15 northing @30 class;
data _null_; set engrw_6u;
file pengrw_6; put @1 easting @15 northing @30 class;
data _null_; set regrw_5u;
file pregrw_5; put @1 easting @15 northing @30 class;
data _null_; set regrw_6u;
file pregrw_6; put @1 easting @15 northing @30 class;
```

Copying site files to the ULTRIX system to create raster and vector files and to average parameters by map polygones

```
dcp -v 46.6/major/mixissjo::'[cs.major.nchristy.outmaps]chu5.pts' chu5.pts
#
s.in.ascii sites=chu5 input=chu5.pts
#
s.surf.idw input=chu5 output=chu5
#
r.contour input=chu5 output=chu5 minlevel=0 maxlevel=15 step=1
#
r.average base=crop.districts cover=chu5 output=avg.cropdist.chu5
#
r.average base=regional.municipalities cover=chu5 output=avg.regmun.chu5
#
r.report map=crop.districts,chu5 units=k output=cropdist.chu5
#
r.report map=regional.municipalities,chu5 units=k output=regmun.chu5
```

category file for regional municipalities

```
# 15 categories
Corn Heat Units under Global Warming

0.00 0.00 0.00 0.00
0:800 CHU
0:800 CHU
1:1000 CHU
2:1200 CHU
3:1400 CHU
4:1600 CHU
5:1800 CHU
6:2000 CHU
7:2200 CHU
8:2400 CHU
9:2600 CHU
10:2800 CHU
11:3000 CHU
12:3200 CHU
13:3400 CHU
14:3600 CHU
15:3800 CHU
```

Appendix A-IV.7: Averaging outputs by Crop Reporting Districts and Regional Municipalities of Alberta.

```
OPTIONS LS=80;

filename chu5 '[CS.MAJOR.nchristy.outmaps]crpdstchu5.cat';
filename chu6 '[CS.MAJOR.nchristy.outmaps]crpdstchu6.cat';
filename gdd0_5 '[CS.MAJOR.nchristy.outmaps]crpdstgdd0_5.cat';
filename gdd0_6 '[CS.MAJOR.nchristy.outmaps]crpdstgdd0_6.cat';
filename gdd5_5 '[CS.MAJOR.nchristy.outmaps]crpdstgdd5_5.cat';
filename gdd5_6 '[CS.MAJOR.nchristy.outmaps]crpdstgdd5_6.cat';
filename gdd8_5 '[CS.MAJOR.nchristy.outmaps]crpdstgdd8_5.cat';
filename gdd8_6 '[CS.MAJOR.nchristy.outmaps]crpdstgdd8_6.cat';
filename gdd10_5 '[CS.MAJOR.nchristy.outmaps]crpdstgdd10_5.cat';
filename gdd10_6 '[CS.MAJOR.nchristy.outmaps]crpdstgdd10_6.cat';
filename hdd18_5 '[CS.MAJOR.nchristy.outmaps]crpdsthdd18_5.cat';
filename hdd18_6 '[CS.MAJOR.nchristy.outmaps]crpdsthdd18_6.cat';
filename ffd_5 '[CS.MAJOR.nchristy.outmaps]crpdstffd_5.cat';
filename ffd_6 '[CS.MAJOR.nchristy.outmaps]crpdstffd_6.cat';
filename engrow_5 '[CS.MAJOR.nchristy.outmaps]crpdstengrow_5.cat';
filename engrow_6 '[CS.MAJOR.nchristy.outmaps]crpdstengrow_6.cat';
filename regrow_5 '[CS.MAJOR.nchristy.outmaps]crpdstregrow_5.cat';
filename regrow_6 '[CS.MAJOR.nchristy.outmaps]crpdstregrow_6.cat';

filename rchu5 '[CS.MAJOR.nchristy.outmaps]rgmnchu5.cat';
filename rchu6 '[CS.MAJOR.nchristy.outmaps]rgmnchu6.cat';
filename rgdd0_5 '[CS.MAJOR.nchristy.outmaps]rgmngdd0_5.cat';
filename rgdd0_6 '[CS.MAJOR.nchristy.outmaps]rgmngdd0_6.cat';
filename rgdd5_5 '[CS.MAJOR.nchristy.outmaps]rgmngdd5_5.cat';
filename rgdd5_6 '[CS.MAJOR.nchristy.outmaps]rgmngdd5_6.cat';
filename rgdd8_5 '[CS.MAJOR.nchristy.outmaps]rgmngdd8_5.cat';
filename rgdd8_6 '[CS.MAJOR.nchristy.outmaps]rgmngdd8_6.cat';
filename rgdd10_5 '[CS.MAJOR.nchristy.outmaps]rgmngdd10_5.cat';
filename rgdd10_6 '[CS.MAJOR.nchristy.outmaps]rgmngdd10_6.cat';
filename rhdd18_5 '[CS.MAJOR.nchristy.outmaps]rgmnhdd18_5.cat';
filename rhdd18_6 '[CS.MAJOR.nchristy.outmaps]rgmnhdd18_6.cat';
filename rffd_5 '[CS.MAJOR.nchristy.outmaps]rgmnffd_5.cat';
filename rffd_6 '[CS.MAJOR.nchristy.outmaps]rgmnffd_6.cat';
filename rengrw_5 '[CS.MAJOR.nchristy.outmaps]rgmnengrow_5.cat';
filename rengrw_6 '[CS.MAJOR.nchristy.outmaps]rgmnengrow_6.cat';
filename rregrw_5 '[CS.MAJOR.nchristy.outmaps]rgmnregrow_5.cat';
filename rregrw_6 '[CS.MAJOR.nchristy.outmaps]rgmnregrow_6.cat';

filename crpdst1 '[CS.MAJOR.nchristy.outmaps]crpdst.av1';
filename crpdst2 '[CS.MAJOR.nchristy.outmaps]crpdst.av2';
filename crpdst3 '[CS.MAJOR.nchristy.outmaps]crpdst.av3';
filename regmun1 '[CS.MAJOR.nchristy.outmaps]regmun.av1';
filename regmun2 '[CS.MAJOR.nchristy.outmaps]regmun.av2';
filename regmun3 '[CS.MAJOR.nchristy.outmaps]regmun.av3';

DATA chu5; INFILE chu5; INPUT cat chu5 ;
proc sort; by cat;
DATA chu6; INFILE chu6; input cat chu6 ;
long=long*-1;
proc sort; by cat;

DATA gdd0_5; INFILE gdd0_5; input cat  gdd0_5 ;
proc sort; by cat;
DATA gdd0_6; INFILE gdd0_6; input cat  gdd0_6 ;
proc sort; by cat;

DATA gdd5_5; INFILE gdd5_5; input cat  gdd5_5 ;
proc sort; by cat;
DATA gdd5_6; INFILE gdd5_6; input cat  gdd5_6 ;
proc sort; by cat;
```

```
DATA gdd8_5; INFILE gdd8_5; input cat  gdd8_5 ;
proc sort; by cat;
DATA gdd8_6; INFILE gdd8_6; input cat  gdd8_6 ;
proc sort; by cat;

DATA gdd10_5; INFILE gdd10_5; input cat  gdd10_5 ;
proc sort; by cat;
DATA gdd10_6; INFILE gdd10_6; input cat  gdd10_6 ;
proc sort; by cat;

DATA hdd18_5; INFILE hdd18_5; input cat  hdd18_5 ;
proc sort; by cat;
DATA hdd18_6; INFILE hdd18_6; input cat  hdd18_6 ;
proc sort; by cat;

DATA ffd_5; INFILE ffd_5; input cat  ffd_5 ;
proc sort; by cat;
DATA ffd_6; INFILE ffd_6; input cat  ffd_6 ;
proc sort; by cat;

DATA regrow_5; INFILE regrow_5; input cat  regrow_5 ;
proc sort; by cat;
DATA regrow_6; INFILE regrow_6; input cat  regrow_6 ;
proc sort; by cat;

DATA engrow_5; INFILE engrow_5; input cat  engrow_5 ;
proc sort; by cat;
DATA engrow_6; INFILE engrow_6; input cat  engrow_6 ;
proc sort; by cat;

data crpdst; merge chu5 chu6 gdd0_5 gdd0_6 gdd5_5 gdd5_6 gdd8_5 gdd8_6 gdd10_5
gdd10_6 hdd18_5 hdd18_6 ffd_5 ffd_6 regrow_5 regrow_6 engrow_5 engrow_6;
by cat;
clschu5=chu5*200+700;  clschu6=chu6*200+700;
clsgdd05=gdd0_5*200+900; clsgdd06=gdd0_6*200+900;
clsgdd55=gdd5_5*200+500; clsgdd56=gdd5_6*200+500;
clsgdd85=gdd8_5*100+300; clsgdd86=gdd8_6*100+300;
clsgdd15=gdd10_5*100+100; clsgdd16=gdd10_6*100+100;
clshdd5=hdd18_5*400+3000; clshdd6=hdd18_6*400+3000;
clsffd5=ffd_5*20+70;     clsffd6=ffd_6*20+70;
clsrgrw5=regrow_5*10+30; clsrgrw6=regrow_6*10+30;
clsngrw5=engrow_5*10+170; clsngrw6=engrow_6*10+170;
if cat=1 then cd='MedicineHat/Foremost'; if cat=2 then cd='Brooks/Lethbridge';
if cat=3 then cd='Claresholm/Cardson'; if cat=4 then cd='Hanna/Empress';
if cat=5 then cd='Drumheller/Vulcan'; if cat=6 then cd='Calgary/Olds';
if cat=7 then cd='Stettler/Wainwright'; if cat=8 then cd='RedDeer';
if cat=9 then cd='RockyMountain-Region'; if cat=10 then cd='Camrose/Vermilion';
if cat=11 then cd='Edmonton'; if cat=12 then cd='LacLaBiche/StPaul';
if cat=13 then cd='Barrhead/Athabasca'; if cat=14 then cd='Edmonton-West';
if cat=15 then cd='NorthPeace'; if cat=16 then cd='SouthPeace';

proc sort; by cat;

proc print; var cat cd clschu6 clschu5 clsgdd06 clsgdd05 clsgdd56 clsgdd55;
proc print; var cat cd clsgdd86 clsgdd85 clsgdd16 clsgdd15 clshdd6 clshdd5 ;
proc print; var cat cd clsffd6 clsffd5 clsrgrw6 clsrgrw5;

data _null_; set crpdst;
clschu6=int(clschu6); clschu5=int(clschu5); clsgdd06=int(clsgdd06);
clsgdd05=int(clsgdd05); clsgdd56=int(clsgdd56); clsgdd55=int(clsgdd55);
file crpdst1;
put @1 cat @5 cd @40 clschu6 clschu5 clsgdd06 clsgdd05 clsgdd56 clsgdd55;
data _null_; set crpdst;
clsgdd86=int(clsgdd86); clsgdd85=int(clsgdd85); clsgdd16=int(clsgdd16);
clsgdd15=int(clsgdd15); clshdd6=int(clshdd6); clshdd5=int(clshdd5);
file crpdst2;
put @1 cat @5 cd @40 clsgdd86 clsgdd85 clsgdd16 clsgdd15 clshdd6 clshdd5 ;
data _null_; set crpdst;
```

```
clsffd6=int(clsffd6); clsffd5=int(clsffd5);
clsrgrw6=int(clsrgrw6); clsrgrw5=int(clsrgrw5);
file crpdst3;
put @1 cat @5 cd @40 clsffd6 clsffd5 clsrgrw6 clsrgrw5;

data rchu5; infile rchu5; INPUT cat chu5 ;
proc sort; by cat;
data rchu6; infile rchu6; input cat chu6 ;
proc sort; by cat;

data rgdd0_5; infile rgdd0_5; input cat  gdd0_5 ;
proc sort; by cat;
data rgdd0_6; infile rgdd0_6; input cat  gdd0_6 ;
proc sort; by cat;

data rgdd5_5; infile rgdd5_5; input cat  gdd5_5 ;
proc sort; by cat;
data rgdd5_6; infile rgdd5_6; input cat  gdd5_6 ;
proc sort; by cat;

data rgdd8_5; infile rgdd8_5; input cat  gdd8_5 ;
proc sort; by cat;
data rgdd8_6; infile rgdd8_6; input cat  gdd8_6 ;
proc sort; by cat;

data rgdd10_5; infile rgdd10_5; input cat  gdd10_5 ;
proc sort; by cat;
data rgdd10_6; infile rgdd10_6; input cat  gdd10_6 ;
proc sort; by cat;

data rhdd18_5; infile rhdd18_5; input cat  hdd18_5 ;
proc sort; by cat;
data rhdd18_6; infile rhdd18_6; input cat  hdd18_6 ;
proc sort; by cat;

data rffd_5; infile rffd_5; input cat  ffd_5 ;
proc sort; by cat;
data rffd_6; infile rffd_6; input cat  ffd_6 ;
proc sort; by cat;

data rregrw_5; infile rregrw_5; input cat  regrow_5 ;
proc sort; by cat;
data rregrw_6; infile rregrw_6; input cat  regrow_6 ;
proc sort; by cat;

data rengrw_5; infile rengrw_5; input cat  engrow_5 ;
proc sort; by cat;
data rengrw_6; infile rengrw_6; input cat  engrow_6 ;
proc sort; by cat;

data regmun; merge rchu5 rchu6 rgdd0_5 rgdd0_6 rgdd5_5 rgdd5_6
rgdd8_5 rgdd8_6 rgdd10_5 rgdd10_6 rhdd18_5 rhdd18_6 rffd_5 rffd_6
rregrw_5 rregrw_6 rengrw_5 rengrw_6; by cat;
clschu5=chu5*200+700;  clschu6=chu6*200+700;
clsgdd05=gdd0_5*200+900; clsgdd06=gdd0_6*200+900;
clsgdd55=gdd5_5*200+500; clsgdd56=gdd5_6*200+500;
clsgdd85=gdd8_5*100+300; clsgdd86=gdd8_6*100+300;
clsgdd15=gdd10_5*100+100; clsgdd16=gdd10_6*100+100;
clshdd5=hdd18_5*400+3000; clshdd6=hdd18_6*400+3000;
clsffd5=ffd_5*20+70;     clsffd6=ffd_6*20+70;
clsrgrw5=regrow_5*10+30; clsrgrw6=regrow_6*10+30;
clsngrw5=engrow_5*10+170; clsngrw6=engrow_6*10+170;
if cat=76 then county='Cold Lake Air Weapons Range';
if cat=1 then county='Improvement District 24';
if cat=2 then county='Improvement District 23';
if cat=3 then county='Improvement District 22';
if cat=4 then county='Improvement District 18';
if cat=5 then county='Improvement District 17';
```

```
if cat=6 then county='Improvement District 21';
if cat=7 then county='Improvement District 20';
if cat=8 then county='Fairview';
if cat=9 then county='Peace';
if cat=10 then county='Spirit River';
if cat=11 then county='Improvement District 19';
if cat=12 then county='Smoky River';
if cat=13 then county='Grande Prairie';
if cat=14 then county='Improvement District 16';
if cat=15 then county='Improvement District 15';
if cat=16 then county='Athabasca';
if cat=17 then county='Barrhead';
if cat=18 then county='Westlock';
if cat=19 then county='Thorhild';
if cat=20 then county='Smoky Lake';
if cat=21 then county='St. Paul';
if cat=22 then county='Bonnyville';
if cat=23 then county='Two Hills';
if cat=24 then county='Vermilion River';
if cat=25 then county='Minburn';
if cat=26 then county='Beaver';
if cat=27 then county='Lamont';
if cat=28 then county='Improvement District 13';
if cat=29 then county='Strathcona';
if cat=30 then county='Sturgeon';
if cat=31 then county='Lac Ste. Anne';
if cat=32 then county='Parkland';
if cat=33 then county='Improvement District 14';
if cat=34 then county='Improvement District 12';
if cat=35 then county='Improvement District 9';
if cat=36 then county='Clearwater';
if cat=37 then county='Brazeau';
if cat=38 then county='Leduc';
if cat=39 then county='Wetaskiwin';
if cat=40 then county='Camrose';
if cat=41 then county='Ponoka';
if cat=42 then county='Flagstaff';
if cat=43 then county='Wainwright';
if cat=44 then county='Provost';
if cat=45 then county='Special Area 4';
if cat=46 then county='Special Area 3';
if cat=47 then county='Paintearth';
if cat=48 then county='Stettler';
if cat=49 then county='Lacombe';
if cat=50 then county='Red Deer';
if cat=51 then county='Mountain View';
if cat=52 then county='Kneehill';
if cat=53 then county='Starland';
if cat=54 then county='Special Area 2';
if cat=55 then county='Acadia Valley';
if cat=56 then county='Municipal District 7';
if cat=57 then county='Wheatland';
if cat=58 then county='Rocky View';
if cat=59 then county='Bighorn';
if cat=60 then county='Improvement District 8';
if cat=61 then county='Improvement District 5';
if cat=62 then county='Foothill';
if cat=63 then county='Vulcan';
if cat=64 then county='Newell';
if cat=65 then county='Cypress';
if cat=66 then county='CFB Suffield';
if cat=67 then county='Forty Mile';
if cat=68 then county='Warner';
if cat=69 then county='Taber';
if cat=70 then county='Lethbridge';
if cat=71 then county='Cardston';
if cat=72 then county='Willow Creek';
if cat=73 then county='Pincher Creek';
```

```
if cat=74 then county='Improvement District 4';
if cat=75 then county='Improvement District 6';
if cat=77 then county='CFB Wainwright';

proc sort; by cat;

proc print; var cat county clschu6 clschu5 clsgdd06 clsgdd05 clsgdd56 clsgdd55;
proc print; var cat county clsgdd86 clsgdd85 clsgdd16 clsgdd15 clshdd6 clshdd5 ;
proc print; var cat county clsffd6 clsffd5 clsrgrw6 clsrgrw5;


data _null_; set regmun;
clschu6=int(clschu6); clschu5=int(clschu5); clsgdd06=int(clsgdd06);
clsgdd05=int(clsgdd05); clsgdd56=int(clsgdd56); clsgdd55=int(clsgdd55);
file regmun1;
put @1 cat @5 county @40 clschu6 clschu5 clsgdd06 clsgdd05 clsgdd56 clsgdd55;
data _null_; set regmun;
clsgdd86=int(clsgdd86); clsgdd85=int(clsgdd85); clsgdd16=int(clsgdd16);
clsgdd15=int(clsgdd15); clshdd6=int(clshdd6); clshdd5=int(clshdd5);
file regmun2;
put @1 cat @5 county @40 clsgdd86 clsgdd85 clsgdd16 clsgdd15 clshdd6 clshdd5 ;
data _null_; set regmun;
clsffd6=int(clsffd6); clsffd5=int(clsffd5);
clsrgrw6=int(clsrgrw6); clsrgrw5=int(clsrgrw5);
file regmun3;
put @1 cat @5 county @40 clsffd6 clsffd5 clsrgrw6 clsrgrw5;
```

Appendix A-V.1a: Command file to calculate statistics on precipitation

Name: precip.com

```
$ set verify = (procedure)
$ for precip_stat
$ link precip_stat,grdname
$ run precip_stat
$ set noverify
```

Appendix A-V.1b: Basic program for precipitation

```
C*****************************************************************
C task: To calculate annual mean total precipitation  for each grid point
C*****************************************************************

      CHARACTER*80 m_CAR,sdm_CAR,nm_CAR
      CHARACTER OUTDIR*25,FILENAME*15
      CHARACTER WEAT_DIR*19
      REAL XILAT,XILNG,m(12),sdm(12),nm(12)

      OUTDIR='[cs.toure.WEATHER]'
      WEAT_DIR='$42$DUC3:[BARR.SN5]'
      OPEN(12,FILE='pfiles.tmp',STATUS='OLD')
      OPEN(13,FILE='precip.dat',carriagecontrol='list',
     &     STATUS='new')

      NREC= 5000 !number of records (STATION) in the sas job file

       DO I=1,NREC
        READ(12,505,end=100) FILENAME
        CALL GRIDNAM(FILENAME,XILAT,XILNG)
C*************************************************************
C  LOADING THE WEATHER STATISTICS FOR THE GRID-POINT
C*************************************************************
        CALL WEAT_STAT(WEAT_DIR,FILENAME,m,sdm,nm)

        train=0.0
        tsdm=0.0
        tnm=0.0
        do j=1,12
          train=train+m(j)
          tsdm=tsdm+sdm(j)
          tnm=tnm+nm(j)
        enddo
       write(13,500) filename,xilat,xilng,train,tsdm,tnm
       ENDDO !read of pfiles.tmp (12) with weather files

100    CLOSE(12)

505    FORMAT(A15)
500    FORMAT(4X,a8,5(2x,F7.2))

       STOP
       END
c*****************************************************************
       SUBROUTINE WEAT_STAT(dir,filein,m,sdm,nm)
c*****************************************************************
       character filein*15,dir*19
       real rainc,nrainc,sdrainc
       real rain(30,12),sdrain(30,12),nrain(30,12)
       real m(12),sdm(12),nm(12)

        call STAT_MONTH(dir,FILEIN,nyear,rain,
     &      nrain,sdrain)


        do i=1,12
            rainc=0.
            sdrainc=0.
            nrainc=0.
          do k=1,nyear
            rainc=rainc+rain(k,i)
            sdrainc=sdrainc+sdrain(k,i)
            nrainc=nrainc+nrain(k,i)
          enddo
```

```
      rn(i)=rainc/nyear
      sdrn(i)=sdrainc/nyear
      nrn(i)=nrainc/nyear

    enddo

50    FORMAT(A80)

    RETURN
    end
c*****************************************************************
C  Weather file format for EPIC Input file
    SUBROUTINE STAT_MONTH(dir,filein,ijj,rainm,
   &     nrain,sdrain)
C  Monthly statistics of precipitation (28/06/93)
c*****************************************************************

    character filein*15,dir*19
    integer idim(12)
    real rain(31)
    real rainc,nrainc,strain
    real nrain(30,12),sdrain(30,12)
    real rainm(30,12),drainm(30,12)
    real p1,p2,p3,p4,p5,p6

    data idim/31,28,31,30,31,30,31,31,30,31,30,31/

    open(9,file=dir//filein,status='old')

    miss=0
    ityear=30
    itmiss=0
    do j=1,ityear  !number of year including missing data
      iyr=1959+j ! starting from 1960 to 1989
      itmiss=itmiss+miss
      jj=j-itmiss

     do i=1,12
       if (mod(iyr,4).eq.0) then
          idim(2)=29
       else
          idim(2)=28
       endif
       id=idim(i)

       rainc=0.0
       strain=0.0
       nrainc=0.0

       do k=1,id
          read(9,*,end=100) p1,p2,p3,p4,p5,p6
          if (p1.lt.-90.0.or.p2.lt.-90.0.or.p4
   &          .lt.-90.0.or.p5.lt.-90.0.or.p6.
   &          lt.-90.0) then
             miss=1
             goto 10
          else if (miss.eq.0) then
             rain(k)=p6
             rainc=rainc+p6
          endif
          if (p4.gt.0.0) nrainc=nrainc+1.
10      enddo !day
       if (miss.eq.0) then
          nrain(jj,i)=nrainc
          rainm(jj,i)=rainc
          drainm(jj,i)=rainc/id
       else
          goto 20
```

```
        endif

        do kk=1,id
           strain=strain+(rain(kk)-drainm(jj,i))**2
        enddo

        sdrain(jj,i)=sqrt(strain/id)

20      enddo !month
     enddo ! year
     ijj=jj
100  close(9)

     return
     END
```

Appendix A-V.2a: Command file for temperature

Name: temp.com

```
$ set verify = (procedure)
$ flr temp4
$ flr temp6
```

Appendix A-V.2b. Basic program to calculate annual mean temperature

```
C*****************************************************************************
C Name: Temp6.for case of baseline SN6
C Task: To calculate annual mean temperature for the 166 weather grid boxes
C*****************************************************************************
      CHARACTER OUTDIR*18,INDIR*20,RECORD*80,FILENAME*12
      CHARACTER FIL*25,WEATD*25

      INDIR='$42$DUC1:[MAJOR.SN6]'
      OUTDIR='[cs.toure.weather]'
      WEATD='$42$DUC1:[MAJOR.SEEDWTH6]'

      OPEN(10,FILE='input6.wth',STATUS='OLD')

      NREC=50000
      DO J=1,NREC
        READ(10,100,END=20) FILENAME
        OPEN(12,FILE='temp_template.sas',STATUS='OLD')

        CALL readtmax (FILENAME,date)

        OPEN(13,FILE=OUTDIR//FILENAME(5:8)//'_'//
     &      FILENAME(3:3)//'.SAS'
     &     ,CARRIAGECONTROL='LIST', STATUS='NEW')

        DO I=1,NREC
          READ(12,200,END=10) RECORD
          IF(I.EQ.2) RECORD(17:58)=
     &        ' "'//WEATD//FILENAME//'";'
          IF(I.EQ.6) THEN
            WRITE(RECORD(26:30),'(f5.1)') date
          ENDIF
          IF(RECORD(1:5).EQ.'FNAME')
     &       RECORD(7:25)='"'//FILENAME//'";'
          WRITE(13,200) RECORD

        ENDDO
10      CLOSE(12)
        CLOSE(13)
        CALL LIB$SPAWN ('WAIT 00:05:00')
        CALL LIB$SPAWN ('SASBATCH '//OUTDIR//FILENAME(5:8)//'_'
     &      //FILENAME(3:3))
      ENDDO
20    CLOSE(11)

100   FORMAT(A12)
505   FORMAT(4X,A55)
600   FORMAT(2X,I4,2X,I3,2X,A55)
200   FORMAT(A80)
      STOP
      END
c*****************************************************************************
      SUBROUTINE Readtmax(FILED,GR)
C     Read the average day at a grid point with maximum temperature
C*****************************************************************************
      CHARACTER GFILE*12,FILED*12,STN*4,STN0*4
      INTEGER IDIM(12)

      GFILE='DATEMAX'//FILED(3:3)//'.LL'
      OPEN(11,FILE=GFILE,STATUS='OLD')
      NREC=200
      STN=FILED(5:8)
      DO I =1,NREC
         READ(11,200,END=20) STN0,GR0
         IF (STN.EQ.STN0) THEN
```

```
          GR=GR0
          GOTO 20
        ENDIF
      ENDDO
20    CLOSE(11)
200   FORMAT(6X,A4,6X,F5.1)
      RETURN
      END
```

Appendix A-V.3a: Auxiliary file

```
C*****************************************************************
C Example of template file to generate appropriate sas program
C  "temp_template.sas" for a grid point
C*****************************************************************

options ls=80;
filename sasdata
data work1;
 infile sasdata;
  input year month jln rdn tmax tmin rain snow precip;
cosday=cos(0.017457*(jln-      ));

PROC REG OUTEST=EST NOPRINT;
M1: MODEL tmax=cosday;

DATA WORK4; SET EST;
LENGTH FNAME $23;
FNAME=
KEEP INTERCEP cosday FNAME;
PROC PRINT;
```

Appendix A-V.4a: Command file to generate seeding dates for 166 grids

Name: seed.com

```
$ set verify = (procedure)
$ flr seeding4
$ flr seeding6
```

Appendix A-V.4b: Basic program to calculate seeding dates

```
C*****************************************************************
C Name: Seeding6.for
C       example for actual climate (SN6)
C       The seeding date model is initialized 10 days before
C          winter wheat spring regrowth
C*****************************************************************
      CHARACTER OUTDIR*25,INDIR*20,RECORD*80,FILENAME*12
      CHARACTER FIL*25,WEAT*25

      INDIR='$42$DUC1:[MAJOR.SN6]'
      OUTDIR='$42$DUC1:[MAJOR.SEEDWTH6]'

      OPEN(10,FILE='FILES6.TMP',STATUS='OLD')

      NREC=50000
      DO J=1,NREC
        READ(10,100,END=20) FILENAME
        OPEN(12,FILE='SEED.TMP',STATUS='OLD')
        CALL REGROWTH (FILENAME,IGROWTH)
        ISTART=IGROWTH-10
        OPEN(13,FILE=OUTDIR//FILENAME(5:8)//'_'//
     &     FILENAME(3:3)//'.SAS'
     &     ,CARRIAGECONTROL='LIST', STATUS='NEW')
        DO I=1,NREC
          READ(12,200,END=10) RECORD
          IF(I.EQ.2) RECORD(17:58)=
     &       ' "//OUTDIR//FILENAME//"';
          IF(I.EQ.8) THEN
            WRITE(RECORD(7:9),'(I3)') ISTART
            RECORD(10:10)=';'
          ENDIF
          IF(RECORD(1:5).EQ.'FNAME')
     &       RECORD(7:25)='"//FILENAME//"';
          WRITE(13,200) RECORD

        ENDDO
10      CLOSE(12)
        CLOSE(13)
        CALL LIB$SPAWN ('WAIT 00:03:00')
        CALL LIB$SPAWN ('SASBATCH '//OUTDIR//FILENAME(5:8)//'_'
     &     //FILENAME(3:3))
      ENDDO
20    CLOSE(11)

100   FORMAT(A12)
505   FORMAT(4X,A55)
600   FORMAT(2X,I4,2X,I3,2X,A55)
200   FORMAT(A80)
      STOP
      END
c*********************************************************
      SUBROUTINE REGROWTH(FILED,IGR)
c*********************************************************
      CHARACTER GFILE*12,FILED*12,STN*4,STN0*4
      INTEGER IDIM(12)

      GFILE='REGROW_'//FILED(3:3)//'.LL'
      OPEN(11,FILE=GFILE,STATUS='OLD')
      NREC=200
      STN=FILED(5:8)
      DO I =1,NREC
         READ(11,200,END=20) STN0,GR0
         IF (STN.EQ.STN0) THEN
           IGR=NINT(GR0)
```

```
          GOTO 20
        ENDIF
      ENDDO
20    CLOSE(11)
200   FORMAT(6X,A4,19X,F5.1)
      RETURN
      END
```

Appendix A-V.4c: SAS program template file

Name: seeding.tmp

```
OPTIONS LS=80;
FILENAME weather
data weather; infile weather;
inPUT yr dayno rdn tmax tmin rain snow precip;
year=yr-1900;
proc sort; by year;
data work3; set weather; if dayno<160;
start=
if dayno<start then delete;
days=dayno-90; precip=rain; if year>90 then delete;
retain ttsw 19.5 atsw 19.5 ftsw 1 edep 150 dyse 1 ctr 0 ce 0 tr 0 lai 0
kount 0 ;

****** begin daily calculations ******;

if precip>10 then dyse=1; atsw=atsw+precip; if atsw>ttsw then atsw=ttsw;
ftsw=atsw/ttsw;  temp=(tmax+tmin)/2;
vpmin = 6.107*exp(17.269*tmin/(273.3+tmin));
vpmax = 6.107*exp(17.269*tmax/(273.3+tmax));
delta = exp(21.255-5304/(273+tmax))*(5304/((273+tmax)**2));
vpd = 0.75*(vpmax-vpmin);
sevp=(rdn*exp(-.5*lai)*delta+0.68*0.4*vpd)/(delta+0.68); sevp=sevp*239/583;
if sevp<1.5 then sevp=1.5; sevp=sevp*((dyse+1)**0.5-dyse**0.5);
if ftsw<0.05 then sevp=0; dyse=dyse+1; atsw=atsw-sevp; if atsw<0 then atsw=0;
proc sort; by year dayno;

data work7; set work3; retain k 0 pred 0 y 0;
if year>y then do; pred=0; y=year; k=0; end;
if (tmax>13 and precip<.5 and ftsw<0.9) then k=k+1; else k=0;
if k=4 and pred=0 then pred=dayno;

data work8; set work7; if pred=dayno;
proc sort; by year;
proc means; var pred;
OUTPUT OUT=EST MEAN= STD=;

DATA WORK2;
LENGTH FNAME $15;
FNAME=
PROC PRINT;var FNAME;
```

Appendix A-VI.1a: Command file to create input files for each weather grid and soil combination and execute the EPIC model

```
$ set verify = (procedure)
$ !SPRING WHEAT
$ ! Irrigated wheat
$set default [cs.toure.gis]
$@WI4
$ set default [cs.toure.EPIC.EPICRUN]
$@SN4_WI
$set default [cs.toure.gis]
$@WI5
$ set default [cs.toure.EPIC.EPICRUN]
$@SN5_WI
$set default [cs.toure.gis]
$@WI6
$ set default [cs.toure.EPIC.EPICRUN]
$@SN6_WI
$set default [cs.toure.gis]
$ !Dryland wheat
$@WD4
$ set default [cs.toure.EPIC.EPICRUN]
$@SN4_WD
$set default [cs.toure.gis]
$@WD5
$ set default [cs.toure.EPIC.EPICRUN]
$@SN5_WD
$set default [cs.toure.gis]
$@WD6
$ set default [cs.toure.EPIC.EPICRUN]
$@SN6_WD
$ !Fallow- spring wheat
$set default [cs.toure.gis]
$@WF4
$ set default [cs.toure.EPIC.EPICRUN]
$@SN4_WF
$set default [cs.toure.gis]
$@WF5
$ set default [cs.toure.EPIC.EPICRUN]
$@SN5_WF
$set default [cs.toure.gis]
$@WF6
$ set default [cs.toure.EPIC.EPICRUN]
$@SN6_WF
$ !CANOLA
$ ! Irrigated canola
$set default [cs.toure.gis]
$@CI4
$ set default [cs.toure.EPIC.EPICRUN]
$@SN4_CI
$set default [cs.toure.gis]
$@CI5
$ set default [cs.toure.EPIC.EPICRUN]
$@SN5_CI
$set default [cs.toure.gis]
$@CI6
$ set default [cs.toure.EPIC.EPICRUN]
$@SN6_CI
$set default [cs.toure.gis]
$ !Dryland canola
$@CD4
$ set default [cs.toure.EPIC.EPICRUN]
$@SN4_CD
$set default [cs.toure.gis]
```

```
$@CD5
$ set default [cs.toure.EPIC.EPICRUN]
$@SN5_CD
$set default [cs.toure.gis]
$@CD6
$ set default [cs.toure.EPIC.EPICRUN]
$@SN6_CD
$ !Fallow- canola
$set default [cs.toure.gis]
$@CF4
$ set default [cs.toure.EPIC.EPICRUN]
$@SN4_CF
$set default [cs.toure.gis]
$@CF5
$ set default [cs.toure.EPIC.EPICRUN]
$@SN5_CF
$set default [cs.toure.gis]
$@WC6
$ set default [cs.toure.EPIC.EPICRUN]
$@SN6_CF
$ !CORN
$ ! Irrigated corn
$set default [cs.toure.gis]
$@MI4
$ set default [cs.toure.EPIC.EPICRUN]
$@SN4_MI
$set default [cs.toure.gis]
$@MI5
$ set default [cs.toure.EPIC.EPICRUN]
$@SN5_MI
$set default [cs.toure.gis]
$@MI6
$ set default [cs.toure.EPIC.EPICRUN]
$@SN6_MI
$set default [cs.toure.gis]
$ !Dryland corn
$@MD4
$ set default [cs.toure.EPIC.EPICRUN]
$@SN4_MD
$set default [cs.toure.gis]
$@MD5
$ set default [cs.toure.EPIC.EPICRUN]
$@SN5_MD
$set default [cs.toure.gis]
$@MD6
$ set default [cs.toure.EPIC.EPICRUN]
$@SN6_MD
$ !Fallow- corn
$set default [cs.toure.gis]
$@MF4
$ set default [cs.toure.EPIC.EPICRUN]
$@SN4_MF
$set default [cs.toure.gis]
$@MF5
$ set default [cs.toure.EPIC.EPICRUN]
$@SN5_MF
$set default [cs.toure.gis]
$@MF6
$ set default [cs.toure.EPIC.EPICRUN]
$@SN6_MF
$ !WINTER WHEAT
$ !Fallow- winter wheat
$set default [cs.toure.gis]
$@WWF4
$ set default [cs.toure.EPIC.EPICRUN]
$@SN4_WWF
$set default [cs.toure.gis]
$@WWF5
```

```
$ set default [cs.toure.EPIC.EPICRUN]
$@SN5_WWF
$set default [cs.toure.gis]
$@WWF6
$ set default [cs.toure.EPIC.EPICRUN]
$@SN6_WWF
$ !CRESTED WHEATGRASS
$ !Dryland wheat
$@GD4
$ set default [cs.toure.EPIC.EPICRUN]
$@SN4_GD
$set default [cs.toure.gis]
$@GD5
$ set default [cs.toure.EPIC.EPICRUN]
$@SN5_GD
$set default [cs.toure.gis]
$@GD6
$ set default [cs.toure.EPIC.EPICRUN]
$@SN6_GD
$EXIT
```

Appendix A-VI.1b: Basic program to create EPIC inputs

Command file
Name: WD6.COM

```
$ set verify = (procedure)
$ set default [cs.toure.gis]
$ for wheatdry6
$ for whtsc_stat
$ for grdname
$ link wheatdry6,whtsc_stat,grdname
$ run wheatdry6
```

Basic program

```
C*********************************************************************
C Name: Wheatdry6.for
C task: To generate an input file (EPIC format) for each grid point
C  1: read the grid point file name: SNx_CCxx.MET
C     SNx: Scenario number;
C     CCxx:character allocated to the grid point
C  2: find the soil name of the grid point
C     and generate the corresponding soil information for EPIC
C  3: read the seeding date (generated from the empirical model)
C       for the grid point
C  4: calculate weather statistics (EPIC format) for the grid point
C  5: write all the above information in a file (EPIC input format)
C*********************************************************************

      CHARACTER*80 Tx_CAR,Tn_CAR,sdtx_CAR,
     &  sdtn_CAR,rn_CAR,sdrn_CAR,nrn_CAR,rd_CAR
      CHARACTER NAME*3,SNAME*3,OUTDIR*16,FILENAME*15
      CHARACTER LAT_DEC*5,CLAT*4,CLNG*5,WEAT_DIR*20
      CHARACTER*80 RECORD,SOIL,SOIL_DATA(25)
      CHARACTER*80 SOWING1,SOWING2,HARVEST1,HARVEST2
      CHARACTER*10 XCOORD,YCOORD,SEEDN
      CHARACTER CFC*5,CWPT*5,SOIL_FC*80,SOIL_WPT*80,STN*8
      CHARACTER SOIL_REC*110,ID*1,DAT_DIR*20
      CHARACTER*3 SOIL_NAME(11)
      CHARACTER*3 SOIL1,SOIL2,SOIL3,SOIL4,SOIL5,SOIL6
     &,SOIL7,SOIL8,SOIL9,SOIL10,SOIL11
      REAL RXCOORD,RYCOORD,XILAT,XILNG

      OUTDIR='$42$duc1:[major]'
      DAT_DIR='[CS.TOURE.GIS.DATUM]'
      WEAT_DIR='$42$DUC3:[BARR.SN6B]'
      OPEN(12,FILE=dat_dir//'FILES6.TMP',STATUS='OLD')

      NREC= 5000 !number of records (STATION) in the sas job file

      DO I=1,NREC
        READ(12,505,end=100) FILENAME
        CALL GRIDNAM(FILENAME,XILAT,XILNG)
        XILNG=-XILNG
        WRITE(LAT_DEC(1:5),'(F5.2)') XILAT
C ***********************************************
C  LOOKING FOR THE SOIL NAME FOR A GRID-POINT
C ***********************************************
      OPEN(17,FILE=DAT_DIR//'SOIL_LU.LL',STATUS='OLD')
      SOIL_NAME(1)='  '

        DO J=1,NREC
          READ(17,506,end=104)SLNG,SLAT,SOIL1,SOIL2,SOIL3
     &,SOIL4,SOIL5,SOIL6,SOIL7,SOIL8,SOIL9,SOIL10,SOIL11
```

```
          IF(XILAT.EQ.SLAT.AND.XILNG.EQ.SLNG) THEN
            SOIL_NAME(1)=SOIL1
            SOIL_NAME(2)=SOIL2
            SOIL_NAME(3)=SOIL3
            SOIL_NAME(4)=SOIL4
            SOIL_NAME(5)=SOIL5
            SOIL_NAME(6)=SOIL6
            SOIL_NAME(7)=SOIL7
            SOIL_NAME(8)=SOIL8
            SOIL_NAME(9)=SOIL9
            SOIL_NAME(10)=SOIL10
            SOIL_NAME(11)=SOIL11
            WRITE(*,*) (SOIL_NAME(J1),J1=1,11)
            GOTO 104
          ELSE
          ENDIF
        ENDDO !read SOIL_LU.DAT
104       CLOSE(17)
        JCOUNT=1
        IF(XILAT.NE.SLAT.AND.XILNG.NE.SLNG) GOTO 105

C  ********************************************************
C  SELECT THE SOIL INFORMATION FOR A GIVEN GRID-POINT,
C  BASED ON THE SOIL NAME
C  ********************************************************
        GOTO 405
400     JCOUNT=JCOUNT+1
405     IF(SOIL_NAME(JCOUNT).EQ.'   ') GOTO 105
        OPEN(15,FILE=DAT_DIR//'alsample.epc',STATUS='OLD')

         ICOUNT=0

        DO K=1,NREC
          READ(15,503,end=103) SOIL
           NAME=SOIL(21:23)
          IF(ICOUNT.GT.0.AND.ICOUNT.LT.22) NAME=SOIL_NAME(JCOUNT)
          IF(SOIL_NAME(JCOUNT).EQ.NAME) THEN
            ICOUNT=ICOUNT+1
            SOIL_DATA(ICOUNT)=SOIL
          ENDIF
          IF(ICOUNT.eq.22) GOTO 50
        ENDDO ! read of Alsample.epc (15) - soil information

C*********************************************************
C  LOADING THE WEATHER STATISTICS FOR THE GRID-POINT
C*********************************************************
50      CALL WEAT_STAT(WEAT_DIR,FILENAME,Tx_CAR,Tn_CAR,
     &sdtx_CAR,sdtn_CAR,rn_CAR,sdrn_CAR,nrn_CAR,rd_CAR)

C*********************************************************************
C CALCULATE FIELD CAPACITY (FC) FROM 'AVAILABLE SOIL' GENERATED
C CANSIS, ASSUMING WILTING POINT=0.1 AND UNIFORM LAYERS
C*********************************************************************

      OPEN(18,FILE=DAT_DIR//'ALTA_WAT.GRD',STATUS='OLD')

      DO IJ=1,80
        SOIL_FC(IJ:IJ)=' '
        SOIL_WPT(IJ:IJ)=' '
      ENDDO

      DEPTH=1200.  ! IN MM

      DO JI=1,NREC
          READ(18,*,END=106) WLNG,WLAT,WAT
          IF (WAT.EQ.-99.99) THEN
            WAT=0.00
            WPT=0.00
```

```
        ELSE
          WPT=0.1
        ENDIF
        IF(XILAT.EQ.WLAT.AND.XILNG.EQ.WLNG) THEN
          FC=WAT/DEPTH +WPT
          GOTO 106
        ELSE
          FC=0.0
        ENDIF
      ENDDO
106   CLOSE(18)

      WRITE(CFC,'(F5.3)') FC
      WRITE(CWPT,'(F5.3)') WPT

      DO KI=1,10
       I1=(2*KI-1)*4
       IF(KI.LE.6) THEN
         SOIL_FC(I1:I1+4)=CFC
         SOIL_WPT(I1:I1+4)=CWPT
       ELSE
         SOIL_FC(I1:I1+4)='0.000'
         SOIL_WPT(I1:I1+4)='0.000'
       ENDIF
      ENDDO
      WRITE(*,*) filename,SOIL_NAME(JCOUNT)

      WRITE(*,*) SOIL_WPT
      WRITE(*,*) SOIL_FC

      SOIL_DATA(4)=SOIL_WPT
      SOIL_DATA(5)=SOIL_FC

C     ************************************************
C     READ THE SEEDING DATE FOR A GIVEN GRID-POINT
C     ************************************************
      if(filename(3:3).eq.'4') seedn='seedsc4.il'
      if(filename(3:3).eq.'5') seedn='seedsc5.il'
      if(filename(3:3).eq.'6') seedn='seedsc6.il'

      OPEN(14,FILE='[cs.toure.seeding]'//SEEDN,STATUS='OLD')

        DO J=1,NREC
          READ(14,600,end=102)STN,DLAT,DLNG,INUM,DATE,STD
          DLNG=-DLNG
          IF(XILAT.EQ.DLAT.AND.XILNG.EQ.DLNG) THEN
            IGRID_DATE=NINT(DATE)
          GOTO 102
          ENDIF
        ENDDO !read date.il
102     CLOSE(14)
        ISOW_JLN=IGRID_DATE
        IMAT_JLN=ISOW_JLN+109
C !102 assumed time for wheat to reach maturity
C !109 assumed time for wheat to reach harvest
C ****time for crop to mature can be simulated from CERES!!!
        CALL MONTH(ISOW_JLN,ISOW_MON,ISOW_DATE)
        CALL MONTH(IMAT_JLN,IMAT_MON,IMAT_DATE)
        DO IJ=1,80
          SOWING1(IJ:IJ)=' '
          SOWING2(IJ:IJ)=' '
          HARVEST1(IJ:IJ)=' '
          HARVEST2(IJ:IJ)=' '
        ENDDO
        WRITE(SOWING1(3:4),'(I2)') ISOW_MON
        WRITE(SOWING1(7:8),'(I2)') ISOW_DATE
        SOWING1(11:12)='71' !EPIC management index
        SOWING1(15:16)='50' !EPICmanagement index
```

```
      SOWING1(24:28)='20.00' !EPIC management index (N kg/ha)
      SOWING1(32:36)='50.00' !EPIC management index (depth of N)

      WRITE(SOWING2(3:4),'(I2)') ISOW_MON
      WRITE(SOWING2(7:8),'(I2)') ISOW_DATE
      SOWING2(12:12)='2' !EPIC management index
      SOWING2(16:16)='3' !EPIC management index

      WRITE(HARVEST1(3:4),'(I2)') IMAT_MON
      WRITE(HARVEST1(7:8),'(I2)') IMAT_DATE
      HARVEST1(11:12)='51' !EPIC MANAGEMENT INDEX

      WRITE(HARVEST2(3:4),'(I2)') IMAT_MON
      WRITE(HARVEST2(7:8),'(I2)') IMAT_DATE
      HARVEST2(11:12)='41' !EPIC MANAGEMENT INDEX

C     ***********************************************
C     NEW INPUT FOR EPIC FOR A GIVEN GRID-POINT
C     ***********************************************
      IF(JCOUNT.EQ.1) ID='A'
      IF(JCOUNT.EQ.2) ID='B'
      IF(JCOUNT.EQ.3) ID='C'
      IF(JCOUNT.EQ.4) ID='D'
      IF(JCOUNT.EQ.5) ID='E'
      IF(JCOUNT.EQ.6) ID='F'
      IF(JCOUNT.EQ.7) ID='G'
      IF(JCOUNT.EQ.8) ID='H'
      IF(JCOUNT.EQ.9) ID='I'
      IF(JCOUNT.EQ.10) ID='J'
      IF(JCOUNT.EQ.11) ID='K'
      OPEN(16,FILE=OUTDIR//FILENAME(1:8)//'WD'//ID//'.DAT'
     &  ,STATUS='NEW',carriagecontrol='list')


C     ***************************************************************
C     READ THE EPIC TEMPLATE FILE AND CHANGE RECORD ACCORDING TO
C     SOIL, SEEDING DATE AND WEATHER INFORMATIONS FOR A GRID-POINT
C     ***************************************************************
      OPEN(13,FILE='[cs.toure.epic]
     &     wheatdry.tmp',STATUS='OLD')

      DO II =1,70 ! NREC IN GRID_TEMPLATE.DAT
        READ(13,503,end=101) RECORD
        IF (II.EQ.2)RECORD(12:14)=soil_name(JCOUNT)
        IF (II.EQ.3)RECORD(1:8)=filename(1:8)
        IF (II.EQ.5) RECORD(60:64)=LAT_DEC(1:5)
        IF (II.EQ.9) RECORD=TX_CAR
        IF (II.EQ.10) RECORD=TN_CAR
        IF (II.EQ.11) RECORD=SDTX_CAR
        IF (II.EQ.12) RECORD=SDTN_CAR
        IF (II.EQ.13) RECORD=RN_CAR
        IF (II.EQ.14) RECORD=SDRN_CAR
        IF (II.EQ.18) RECORD=NRN_CAR
        IF (II.EQ.20) RECORD=RD_CAR
        IF (II.GE.42.AND.II.LE.62)RECORD
     &     =SOIL_DATA(II-40)
        IF (II.EQ.65) RECORD=SOWING1
        IF (II.EQ.66) RECORD(4:16)=SOWING2(4:16)
        IF (II.EQ.67) RECORD=HARVEST1
        IF (II.EQ.68) RECORD=HARVEST2
        IF (RECORD.EQ.'WEATHER.DAT')RECORD=WEAT_DIR//FILENAME
        WRITE(16,503) RECORD
      ENDDO !read of grid_template.dat (13)

101     CLOSE(13)
      CLOSE(16)
103     CLOSE(15)
```

```
      IF(SOIL_NAME(JCOUNT).NE.'  ') GOTO 400
105   ENDDO !read of files.tmp (12) with weather files

100   CLOSE(12)

500   FORMAT(A2)
501   FORMAT(A41)
502   FORMAT(A51)
503   FORMAT(A80)
504   FORMAT(X,2(X,A10),X,A4,X,A3)
505   FORMAT(A15)
506   FORMAT(X,F7.2,X,F5.2,2X,11(A3,7X))
600   FORMAT(2X,A8,3X,F5.2,2X,F6.2,2X,I2,4X,2(2X,F6.2))

      STOP
      END
```

Appendix A-VI.1c: Basic programs to execute EPIC in the VAX/VMS environment

```
$!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
$Name: SN6_WD
$! Example for  dryland spring wheat
$! Batch program to run the EPIC model for grid points
$!
$!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
$ !Adjusted for yield prediction on a grid point basis
$ !Before running this program, input files for EPIC should be
$ !created
$!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
$!
$ set NOverify
$! GET NAMES OF THE EPIC INPUT FILES
$!
$ DIR_NAME="$42$DUC1:[MAJOR.WHEAT6]"
$ DIR/COLUMNS=1/WIDTH=FILENAME=17/OUTPUT=FILES_SN6.TMP 'DIR_NAME'SN6*.dat
$ !
$ OPEN/READ INFILE FILES_SN6WD.TMP
$ GET="READ/END_OF_FILE=END INFILE FILENAME"
$ ! MOVE PAST 1ST 3 RECORDS
$ GET
$ GET
$ GET
$ READ_FILES:
$ GET
$ IF FILENAME .EQS. "" THEN GOTO READ_FILES
$ !
$ ! copy input files from "gridin" directory to "epicrun" directory
$ COPY $42$DUC1:[MAJOR.WHEAT6]'FILENAME' [CS.TOURE.EPIC.EPICRUN]*.*;
$ @EWQ -epy  'FILENAME'
$ !WAIT 00:00:40.00
$ !Remove output files not required for analysis
$ DEL *.SUM*;
$ DEL *.OUT*;
$ DEL [CS.TOURE.EPICRUN]SN6*.dat;
$ GOTO read_files
$ END:
$ DEL *.CMD;*
$ CLOSE INFILE
$ !
$ !Merge output files into one file
$ APPEND/NEW_VERSION/LOG *.EPY*  WD6.TMP
$ CLOSE WD6.TMP
$DEL *.EPY*;
$ COPY WD6.TMP $42$DUC3:[BARR.ASSAN]YIELD.TMP
$ RUN $42$DUC1:[MAJOR.YIELDPROG]CONT_YIELD
$ SET DEFAULT $42$DUC3:[BARR.ASSAN]
$ REN YIELD.LL WD6.LL
$ DEL YIELD.TMP;
$ EXIT
```

Appendix A-VI.1: Auxiliary program

Name: weight_ave.for

```
C*************************************************************
C     GENERATE A FILE CONTAINING THE APPROPRIATES PARAMETERS
C     FROM THE EPIC OUTPUT FILE AND CALCULATE MEAN AND VARIANCE
C     OF YIELDS
C     *FOR A GRID BOX, CALCULATES THE WEIGHTED MEAN YIELD
C      BASED ON AREA AND YIELD OF EACH SOIL TYPE WITHIN THE GRID
C      BOX.
C*************************************************************

      CHARACTER  RECORD*110, FILENAME*15,DIR1*40,DIR2*24
      CHARACTER  SNAME0*3,FILEIN*15
      REAL       LAT1,LNG1,XLAT,XLNG,LAT(5000),LNG(600)
      REAL       YIELD,MYLD,PROY,PRO(600),TAREA
      REAL       ARE(600),AREAS,LATI,LNGI
      INTEGER    NREC


      DIR1='$42$duc1:[major.yieldprog]'
      DIR2='$42$duc1:[MAJOR.OUTDATA]'

      OPEN(11,FILE=DIR2//'INPUT.TMP',STATUS='OLD')
      NREC=10000

      DO JK=1,NREC
        READ(11,250,END=35) FILEIN
        OPEN(12,FILE=dir2//FILEIN,STATUS='OLD')
        nc=3
        IF(FILEIN(5:5).EQ.'.') nc=4
                    OPEN(14,FILE=dir2//FILEIN(1:nc)//'_136.lI',
     &    STATUS='NEW',CARRIAGECONTROL='LIST')

        DO I=1,NREC
          READ(12,200,END=10) XLAT,XLNG,SNAME0,YIELD
          LAT(I)=XLAT
          LNG(I)=XLNG
          OPEN(13,FILE=dir1//'SOIL_LU.lI',STATUS='OLD')
          DO J=1,NREC
            READ(13,300,end=20) LNG1,LAT1,RECORD
            LNG1=-LNG1
            IF(XLAT.EQ.LAT1.AND.XLNG.EQ.LNG1) THEN
              DO J1=1,11
                IK=10*(J1-1)+1
                READ(RECORD(IK+3:IK+9),'(F7.2)') AREA
                IF(RECORD(IK:IK+2).EQ.SNAME0) GOTO 20
              ENDDO
            ENDIF
          ENDDO
20         CLOSE(13)
          PRO(I)=AREA*YIELD
          ARE(I)=AREA
        ENDDO
10       IREC=I-1
        CLOSE(12)

        K=0
        PROY=0.0
        TAREA=0.0
        DO I=1,IREC+1
          TAREA=TAREA+ARE(I)
          PROY=PROY+PRO(I)
```

```
      IF(LAT(I).NE.LAT(I+1).OR.LNG(I)
     &    .NE.LNG(I+1)) THEN
          K=K+1
          MYLD=PROY/TAREA
          LATI=LAT(I)
          LNGI=LNG(I)
          WRITE(14,400) LATI,LNGI,MYLD
          PROY=0.0
          TAREA=0.0
        ENDIF
30    ENDDO
      CLOSE(14)
    ENDDO
35  CLOSE(11)

c200  FORMAT(14X,F5.2,3X,F6.2,2X,A3,3X,F6.2)
200   FORMAT(11X,F5.2,X,F6.2,X,A3,2X,F5.1)
250   FORMAT(A7)
300   format(x,F7.2,X,F5.2,2X,A110)
C300  format(2x,A8,2(2X,F7.2),2X,A3,2(2X,F7.2))
400   format(2x,3(3X,F7.2))
100   FORMAT(A15)
40    STOP
    END
```

Appendix A-VI.2: Commands in the GRASS GIS environment to creat raster and vector files from seeding date site files

```
# case of scenario 6
#
s.in.ascii sites=seed6.s input=seed6.utm
s.surf.idw input=seed6.s output=seed6.ras
db.rreclass input=seed6.ras output=seed6.rec database=seed.db rules=seed.rule
r.poly input=seed6.rec output=seed6.vec
v.support seed6.vec
v.patch input=seed6.vec,border output=seed6.pat
v.support seed6.pat
v.spag map=seed6.pat
v.support map=seed6.pat
v.alabel map=seed6.pat
#
#
#creating a raste a vector file from growth duration site file
# case of corn under scenario 6
#
s.in.ascii sites=md6mat.s input=md6mat.utm
s.surf.idw input=md6mat.s output=md6mat.ras
db.rreclass input=md6mat.ras output=md6mat.rec database=mat.db rules=mat.rule
r.poly input=md6mat.rec output=md6mat.vec
v.support md6mat.vec
v.patch input=md6mat.vec,border output=md6mat.pat
v.support md6mat.pat
v.spag map=md6mat.pat
v.support map=md6mat.pat
v.alabel map=md6mat.pat
#
#
#creating a raste a vector file from crop yield site file
# case of canola under scenario 6
#
s.in.ascii sites=cd6.s input=cd6.utm
s.surf.idw input=cd6.s output=cd6.ras
db.rreclass input=cd6.ras output=cd6.rec database=yield.db rules=yield.rule
r.poly input=cd6.rec output=cd6.vec
v.support cd6.vec
v.patch input=cd6.vec,border output=cd6.pat
v.support cd6.pat
v.spag map=cd6.pat
v.support map=cd6.pat
v.alabel map=cd6.pat
#
```

APPENDIX A-VI.3: Commands in the Grass GIS to average parameters by desired map polygones

```
#Seeding dates
#
# Average by Alberta Crop Reporting Districts
#
r.average base=crop.districts cover=seed4.ras out=seed4_crd.rpt
r.average base=crop.districts cover=seed5.ras out=seed5_crd.rpt
r.average base=crop.districts cover=seed6.ras out=seed6_crd.rpt
#
# Average by Alberta Regional Municipalities
#
r.average base=regional.municipalities cover=seed4.ras out=seed4_mun.rpt
r.average base=regional.municipalities cover=seed5.ras out=seed5_mun.rpt
r.average base=regional.municipalities cover=seed6.ras out=seed6_mun.rpt

#
#  Growth duration
# Average by Alberta Crop Reporting Districts
#
r.average base=crop.districts cover=wd4mat.ras out=wd4mat_crd.rpt
r.average base=crop.districts cover=wd5mat.ras out=wd5mat_crd.rpt
r.average base=crop.districts cover=wd6mat.ras out=wd6mat_crd.rpt
r.average base=crop.districts cover=cd4mat.ras out=cd4mat_crd.rpt
r.average base=crop.districts cover=cd5mat.ras out=cd5mat_crd.rpt
r.average base=crop.districts cover=cd6mat.ras out=cd6mat_crd.rpt
r.average base=crop.districts cover=md4mat.ras out=md4mat_crd.rpt
r.average base=crop.districts cover=md5mat.ras out=md5mat_crd.rpt
r.average base=crop.districts cover=md6mat.ras out=md6mat_crd.rpt
r.average base=crop.districts cover=wwf4mat.ras out=wwf4mat_crd.rpt
r.average base=crop.districts cover=wwf5mat.ras out=wwf5mat_crd.rpt
r.average base=crop.districts cover=wwf6mat.ras out=wwf6mat_crd.rpt
#
# Average by Alberta Regional Municipalities
#
r.average base=regional.municipalities cover=wd4mat.ras out=wd4mat_mun.rpt
r.average base=regional.municipalities cover=wd5mat.ras out=wd5mat_mun.rpt
r.average base=regional.municipalities cover=wd6mat.ras out=wd6mat_mun.rpt
r.average base=regional.municipalities cover=cd4mat.ras out=cd4mat_mun.rpt
r.average base=regional.municipalities cover=cd5mat.ras out=cd5mat_mun.rpt
r.average base=regional.municipalities cover=cd6mat.ras out=cd6mat_mun.rpt
r.average base=regional.municipalities cover=md4mat.ras out=md4mat_mun.rpt
r.average base=regional.municipalities cover=md5mat.ras out=md5mat_mun.rpt
r.average base=regional.municipalities cover=md6mat.ras out=md6mat_mun.rpt
r.average base=regional.municipalities cover=wwf4mat.ras out=wwf4mat_mun.rpt
r.average base=regional.municipalities cover=wwf5mat.ras out=wwf5mat_mun.rpt
r.average base=regional.municipalities cover=wwf6mat.ras out=wwf6mat_mun.rpt
#
# Average by Alberta Soil Landscape polygones
#
r.average base=alberta.soil cover=wd4mat.ras out=wd4mat_slc.rpt
r.average base=alberta.soil cover=wd5mat.ras out=wd5mat_slc.rpt
r.average base=alberta.soil cover=wd6mat.ras out=wd6mat_slc.rpt
r.average base=alberta.soil cover=cd4mat.ras out=cd4mat_slc.rpt
r.average base=alberta.soil cover=cd5mat.ras out=cd5mat_slc.rpt
r.average base=alberta.soil cover=cd6mat.ras out=cd6mat_slc.rpt
r.average base=alberta.soil cover=md4mat.ras out=md4mat_slc.rpt
r.average base=alberta.soil cover=md5mat.ras out=md5mat_slc.rpt
r.average base=alberta.soil cover=md6mat.ras out=md6mat_slc.rpt
r.average base=alberta.soil cover=wwf4mat.ras out=wwf4mat_slc.rpt
r.average base=alberta.soil cover=wwf5mat.ras out=wwf5mat_slc.rpt
r.average base=alberta.soil cover=wwf6mat.ras out=wwf6mat_slc.rpt
```

```
# Yields: example for corn
#
# Average by Alberta Crop Reporting Districts
#
r.average base=crop.districts cover=md4.ras out=md4_crd.rpt
r.average base=crop.districts cover=md5.ras out=md5_crd.rpt
r.average base=crop.districts cover=md6.ras out=md6_crd.rpt
r.average base=crop.districts cover=mf4.ras out=mf4_crd.rpt
r.average base=crop.districts cover=mf5.ras out=mf5_crd.rpt
r.average base=crop.districts cover=mf6.ras out=mf6_crd.rpt
r.average base=crop.districts cover=mi4.ras out=mi4_crd.rpt
r.average base=crop.districts cover=mi5.ras out=mi5_crd.rpt
r.average base=crop.districts cover=mi6.ras out=mi6_crd.rpt
#
# Average by Alberta Regional Municipalities
#
r.average base=regional.municipalities cover=md4.ras out=md4_mun.rpt
r.average base=regional.municipalities cover=md5.ras out=md5_mun.rpt
r.average base=regional.municipalities cover=md6.ras out=md6_mun.rpt
r.average base=regional.municipalities cover=mf4.ras out=mf4_mun.rpt
r.average base=regional.municipalities cover=mf5.ras out=mf5_mun.rpt
r.average base=regional.municipalities cover=mf6.ras out=mf6_mun.rpt
r.average base=regional.municipalities cover=mi4.ras out=mi4_mun.rpt
r.average base=regional.municipalities cover=mi5.ras out=mi5_mun.rpt
r.average base=regional.municipalities cover=mi6.ras out=mi6_mun.rpt
#
# Average by Alberta Soil Landscape polygones
#
r.average base=alberta.soil cover=md4.ras out=md4_slc.rpt
r.average base=alberta.soil cover=md5.ras out=md5_slc.rpt
r.average base=alberta.soil cover=md6.ras out=md6_slc.rpt
r.average base=alberta.soil cover=mf4.ras out=mf4_slc.rpt
r.average base=alberta.soil cover=mf5.ras out=mf5_slc.rpt
r.average base=alberta.soil cover=mf6.ras out=mf6_slc.rpt
r.average base=alberta.soil cover=mi4.ras out=mi4_slc.rpt
r.average base=alberta.soil cover=mi5.ras out=mi5_slc.rpt
r.average base=alberta.soil cover=mi6.ras out=mi6_slc.rpt
```

APPENDIX B

Model outputs by weather grid points.

Appendix B-IV.1: Agroclimatic indices for 166 weather grid points in Alberta for historical (1) and doubled atmospheric CO_2 scenario (2).

Grid	Scenario	CHU	GDD0	GDD5	GDD8	GDD10	HDD18	FFD	REGROW	ENGROW
BC49	1	1578	1581	1009	743	601	5589	125	161	220
BC49	2	2374	2191	1504	1136	925	4175	176	115	268
BC59	1	1276	1344	832	605	482	6142	107	143	194
BC59	2	1997	1896	1258	933	755	4706	151	100	260
BC69	1	1060	1157	699	496	385	6142	88	134	192
BC69	2	1884	1800	1177	861	686	4692	140	95	242
BC77	1	1460	1473	935	696	565	5854	118	103	205
BC77	2	2227	2070	1401	1056	862	4505	163	92	266
BC79	1	1092	1115	710	529	426	6112	78	120	194
BC79	2	1932	1822	1220	926	764	4693	140	84	253
BC85	1	1167	1210	766	574	464	6561	92	162	192
BC85	2	1960	1870	1242	936	770	5193	147	127	260
BC87	1	1356	1402	873	638	510	5984	116	107	200
BC87	2	2167	2026	1355	1009	814	4600	164	95	263
BC89	1	1486	1492	939	683	543	5779	120	112	205
BC89	2	2284	2080	1417	1064	861	4366	156	80	265
BC93	1	1481	1501	951	706	574	6032	119	153	208
BC93	2	2255	2099	1419	1065	867	4700	165	118	265
BC95	1	1174	1236	770	569	456	6466	99	161	190
BC95	2	1978	1885	1243	925	753	5092	153	126	259
BC97	1	1202	1284	782	560	438	6249	107	126	190
BC97	2	1978	1873	1229	902	720	4851	144	99	257
BC99	1	1574	1535	989	734	595	5924	118	107	218
BC99	2	2370	2158	1487	1133	929	4552	165	78	266
BD31	1	1783	1721	1124	835	679	5270	131	103	238
BD31	2	2604	2349	1658	1275	1049	3801	175	59	272
BD33	1	2069	1940	1308	991	817	5125	140	97	260
BD33	2	2843	2554	1854	1459	1220	3628	180	65	276
BD35	1	2216	2057	1407	1074	889	5123	146	98	264
BD35	2	2999	2696	1981	1575	1325	3620	185	63	278
BD37	1	2393	2203	1545	1196	997	4996	152	94	269
BD37	2	3184	2892	2161	1744	1483	3514	188	62	281
BD39	1	2426	2235	1569	1216	1013	5058	153	103	268
BD39	2	3191	2902	2170	1754	1493	3565	187	66	282
BD41	1	1754	1707	1110	826	674	5370	130	124	233
BD41	2	2556	2316	1630	1252	1031	3889	173	83	271
BD43	1	2224	2055	1415	1081	894	5008	146	93	266
BD43	2	3017	2711	2002	1598	1348	3513	183	48	280
BD45	1	2343	2161	1501	1152	955	5022	149	97	267
BD45	2	3119	2813	2095	1683	1426	3515	187	58	281
BD47	1	2462	2261	1582	1221	1013	5062	157	98	267
BD47	2	3227	2915	2182	1763	1499	3569	190	63	283
BD49	1	2456	2250	1580	1222	1016	5152	155	106	267
BD49	2	3217	2905	2178	1761	1500	3658	187	67	282
BD51	1	1572	1559	995	732	590	5568	121	127	217
BD51	2	2384	2169	1500	1138	930	4068	168	85	268
BD53	1	2149	1998	1362	1034	853	5164	143	95	265
BD53	2	2939	2636	1936	1537	1291	3644	181	55	277
BD55	1	2335	2152	1500	1156	962	5212	147	101	266
BD55	2	3103	2809	2097	1690	1435	3692	183	64	280
BD57	1	2437	2232	1565	1210	1005	5255	153	99	267
BD57	2	3189	2876	2157	1744	1485	3758	187	65	280
BD59	1	2561	2335	1661	1295	1082	5173	147	105	269
BD59	2	3292	2982	2257	1840	1576	3691	189	67	284
BD61	1	1658	1602	1045	786	646	5659	118	132	233
BD61	2	2451	2227	1560	1200	992	4196	166	81	268
BD63	1	2159	2008	1374	1048	867	5393	144	99	262
BD63	2	2942	2651	1949	1550	1305	3892	181	66	276

Appendix B-IV.1 (Continued)

Grid	Scenario	CHU	GDD0	GDD5	GDD8	GDD10	HDD18	FFD	REGROW	ENGROW
BD65	1	2311	2130	1476	1134	940	5426	148	111	265
BD65	2	3060	2757	2050	1646	1395	3914	173	69	278
BD67	1	2354	2155	1504	1161	963	5490	144	125	265
BD67	2	3095	2782	2078	1676	1424	3995	180	72	279
BD69	1	2465	2251	1588	1234	1029	5361	146	123	267
BD69	2	3202	2892	2176	1765	1506	3876	184	70	281
BD71	1	1857	1764	1159	861	700	5551	134	117	248
BD71	2	2687	2401	1704	1317	1085	4121	176	79	270
BD73	1	2118	1973	1344	1023	844	5589	142	121	260
BD73	2	2907	2615	1913	1516	1273	4126	177	74	276
BD75	1	2260	2089	1441	1104	914	5563	146	123	264
BD75	2	3013	2710	2006	1605	1356	4085	181	70	277
BD77	1	2262	2088	1460	1131	944	5713	137	128	265
BD77	2	3018	2743	2046	1649	1403	4239	178	86	277
BD79	1	2255	2084	1465	1139	953	5791	134	132	264
BD79	2	3007	2748	2055	1660	1415	4308	175	88	275
BD81	1	1877	1783	1176	875	713	5595	135	121	251
BD81	2	2707	2424	1723	1334	1100	4190	176	78	271
BD83	1	2093	1956	1328	1008	831	5692	139	104	260
BD83	2	2877	2588	1886	1491	1249	4266	178	77	274
BD85	1	2272	2098	1450	1112	919	5641	144	121	264
BD85	2	3033	2724	2016	1613	1362	4203	180	79	277
BD87	1	2193	2030	1408	1086	904	5922	135	131	263
BD87	2	2945	2667	1974	1581	1339	4463	175	95	274
BD89	1	2154	1991	1379	1062	883	6034	131	137	263
BD89	2	2902	2625	1940	1552	1313	4555	168	89	272
BD91	1	1898	1810	1186	876	708	5769	140	130	252
BD91	2	2722	2427	1719	1326	1091	4378	177	82	271
BD93	1	2117	1976	1345	1022	841	5756	140	126	260
BD93	2	2901	2609	1902	1503	1259	4359	177	78	274
BD95	1	2143	1983	1359	1037	856	5766	138	128	261
BD95	2	2912	2611	1915	1520	1277	4350	174	82	274
BD97	1	2110	1953	1337	1020	842	6000	135	134	262
BD97	2	2879	2579	1889	1498	1258	4556	171	88	273
BD99	1	2029	1876	1292	993	824	6208	124	139	261
BD99	2	2800	2524	1851	1473	1241	4746	163	92	271
BE31	1	2285	2118	1495	1171	986	5648	139	126	265
BE31	2	3010	2776	2086	1693	1449	4107	178	73	278
BE41	1	2043	1919	1304	990	813	5625	132	126	251
BE41	2	2875	2592	1897	1506	1266	4034	177	74	276
BE51	1	2429	2231	1572	1220	1017	5320	146	109	267
BE51	2	3162	2871	2162	1756	1500	3772	183	68	280
BE61	1	2428	2230	1582	1233	1031	5512	141	121	267
BE61	2	3134	2859	2164	1763	1510	3976	181	79	279
BE71	1	2431	2228	1584	1236	1034	5681	141	129	266
BE71	2	3130	2851	2158	1759	1507	4175	180	89	279
BE81	1	2253	2076	1450	1121	933	5943	136	135	264
BE81	2	2982	2701	2012	1620	1376	4446	173	95	274
BE91	1	2195	2023	1403	1079	895	6060	134	135	263
BE91	2	2937	2645	1956	1565	1324	4586	171	104	273
CB39	1	1561	1537	994	746	611	5878	116	148	226
CB39	2	2332	2144	1476	1123	924	4646	166	117	265
CB47	1	1515	1550	970	704	562	5632	126	118	214
CB47	2	2317	2146	1451	1080	871	4416	182	94	264
CB49	1	1248	1338	813	581	455	6007	113	138	193
CB49	2	2022	1908	1255	918	733	4748	160	108	252
CB77	1	1504	1543	946	661	508	6256	136	132	207
CB77	2	2320	2096	1416	1044	827	5017	171	104	260
CB79	1	1702	1687	1057	747	581	6151	145	131	229
CB79	2	2552	2275	1564	1168	933	4923	176	112	267
CB85	1	1662	1605	1032	757	608	6176	125	139	234
CB85	2	2458	2201	1525	1158	944	4969	165	88	266

Appendix B-IV.1 (Continued)

Grid	Scenario	CHU	GDD0	GDD5	GDD8	GDD10	HDD18	FFD	REGROW	ENGROW
CB87	1	1736	1662	1075	790	635	6157	132	139	234
CB87	2	2522	2247	1565	1193	974	4952	170	107	266
CB89	1	1802	1717	1111	814	653	6204	138	129	246
CB89	2	2634	2338	1631	1242	1012	4996	174	115	269
CB95	1	1627	1583	1011	734	584	6306	126	141	230
CB95	2	2409	2151	1486	1125	912	5082	156	111	264
CB97	1	1713	1667	1058	758	596	6205	139	135	240
CB97	2	2561	2279	1574	1184	952	4977	173	109	266
CB99	1	1925	1818	1182	859	683	6179	144	132	250
CB99	2	2751	2422	1702	1301	1057	4970	177	105	270
CC15	1	1093	1223	725	503	384	6191	102	161	185
CC15	2	1836	1774	1145	826	649	4813	146	93	239
CC17	1	1158	1276	758	525	401	6201	106	121	190
CC17	2	1925	1838	1195	862	677	4810	154	91	245
CC19	1	1671	1617	1041	767	620	5886	126	104	236
CC19	2	2486	2238	1552	1181	964	4536	172	74	267
CC21	1	1257	1329	817	589	465	6221	108	147	194
CC21	2	2036	1914	1266	933	749	4918	158	109	257
CC23	1	957	1114	646	442	333	6523	98	144	183
CC23	2	1726	1691	1072	762	593	5176	146	103	232
CC25	1	962	1105	646	445	337	6365	93	122	186
CC25	2	1710	1680	1069	763	596	5011	140	90	233
CC27	1	1513	1529	951	680	535	5961	127	108	208
CC27	2	2318	2110	1430	1063	851	4642	162	87	264
CC29	1	1737	1680	1080	789	633	5885	135	118	240
CC29	2	2551	2281	1588	1207	982	4556	172	75	268
CC31	1	1523	1528	966	708	570	5831	121	133	213
CC31	2	2316	2122	1445	1083	877	4583	166	93	264
CC33	1	1154	1274	758	526	401	6135	108	111	192
CC33	2	1944	1849	1203	868	682	4846	155	80	241
CC35	1	1419	1469	901	639	498	6128	125	137	201
CC35	2	2220	2044	1370	1009	801	4861	161	89	256
CC37	1	1731	1691	1072	762	593	5907	137	122	234
CC37	2	2569	2279	1577	1187	953	4639	172	84	266
CC39	1	1814	1741	1125	821	655	5809	139	134	241
CC39	2	2658	2365	1654	1261	1026	4504	178	82	268
CC41	1	1418	1464	903	644	505	5903	122	139	204
CC41	2	2217	2042	1372	1014	810	4656	160	84	258
CC43	1	1494	1506	943	682	542	5971	124	118	210
CC43	2	2286	2090	1414	1054	848	4755	159	84	261
CC45	1	1625	1596	1017	742	595	6100	129	139	224
CC45	2	2400	2167	1489	1123	910	4913	160	92	265
CC47	1	1714	1655	1066	782	628	6126	130	140	237
CC47	2	2506	2241	1557	1183	964	4920	164	92	267
CC49	1	1896	1790	1173	864	695	5911	138	137	247
CC49	2	2717	2406	1699	1307	1071	4639	176	82	271
CC51	1	1278	1375	827	580	446	5980	119	146	192
CC51	2	2057	1929	1270	922	727	4722	158	85	252
CC53	1	1456	1506	921	646	500	6015	130	113	205
CC53	2	2273	2082	1396	1025	810	4797	162	88	259
CC55	1	1561	1560	976	697	547	6151	129	142	222
CC55	2	2396	2165	1477	1103	883	4976	161	95	264
CC57	1	1716	1651	1066	784	630	6170	128	141	239
CC57	2	2503	2237	1555	1183	965	4990	162	93	267
CC59	1	1900	1785	1175	871	703	6018	135	137	251
CC59	2	2716	2404	1702	1312	1078	4763	173	87	270
CC65	1	1592	1607	996	701	543	6150	136	143	222
CC65	2	2425	2191	1487	1101	873	4944	167	102	263
CC67	1	1706	1662	1060	767	607	6193	131	142	235
CC67	2	2510	2243	1551	1171	946	4983	165	99	265
CC69	1	1863	1743	1152	857	693	6185	128	139	249
CC69	2	2656	2349	1665	1285	1058	4925	167	92	269

Appendix B-IV.1 (Continued)

Grid	Scenario	CHU	GDD0	GDD5	GDD8	GDD10	HDD18	FFD	REGROW	ENGROW
CC77	1	1513	1551	952	661	505	6300	131	152	219
CC77	2	2346	2122	1434	1055	831	5021	164	100	262
CC79	1	1698	1657	1052	753	591	6254	134	141	234
CC79	2	2531	2247	1556	1171	941	4952	168	93	267
CC87	1	1470	1531	927	630	471	6419	132	149	214
CC87	2	2326	2109	1414	1031	803	5105	165	103	261
CC89	1	1651	1647	1022	706	534	6358	140	143	232
CC89	2	2546	2271	1548	1146	904	5032	177	102	265
CC97	1	1826	1753	1122	805	631	6299	139	141	247
CC97	2	2643	2339	1621	1224	985	5040	172	106	268
CC99	1	1632	1645	1014	695	521	6371	140	144	230
CC99	2	2512	2250	1525	1124	882	5052	176	107	264
CD11	1	1906	1798	1191	887	721	5954	136	132	255
CD11	2	2705	2408	1717	1333	1101	4592	172	80	271
CD13	1	1949	1828	1221	915	746	5883	133	132	257
CD13	2	2764	2465	1769	1380	1145	4492	173	80	271
CD15	1	2098	1951	1312	982	797	5841	144	134	259
CD15	2	2912	2580	1867	1463	1215	4430	180	81	272
CD17	1	2103	1950	1322	996	813	5960	138	139	259
CD17	2	2915	2590	1885	1485	1239	4531	178	81	273
CD19	1	2091	1937	1316	995	815	6071	135	139	261
CD19	2	2879	2561	1867	1475	1233	4625	174	85	272
CD21	1	1893	1785	1177	873	706	5895	134	137	254
CD21	2	2731	2426	1724	1333	1097	4544	177	83	270
CD23	1	1995	1869	1241	923	746	5897	140	135	257
CD23	2	2826	2500	1791	1393	1150	4513	177	81	272
CD25	1	2185	2023	1360	1012	816	5799	149	133	262
CD25	2	3016	2656	1922	1506	1248	4399	186	80	272
CD27	1	2150	1987	1347	1012	822	5895	142	133	261
CD27	2	2966	2624	1906	1503	1252	4481	183	80	273
CD29	1	2082	1918	1306	987	807	6073	129	133	261
CD29	2	2863	2538	1850	1462	1221	4641	169	84	272
CD31	1	1964	1846	1217	899	724	5883	141	136	254
CD31	2	2808	2481	1765	1364	1121	4540	179	81	272
CD33	1	2013	1867	1250	932	755	5925	138	135	255
CD33	2	2847	2511	1806	1410	1167	4539	175	84	272
CD35	1	2104	1942	1299	962	772	5984	142	134	259
CD35	2	2933	2564	1852	1447	1196	4573	180	82	272
CD37	1	2098	1933	1304	974	788	6065	137	133	256
CD37	2	2918	2566	1860	1460	1212	4645	180	87	272
CD39	1	2061	1906	1283	960	778	6198	134	135	259
CD39	2	2868	2528	1830	1435	1191	4763	175	89	272
CD41	1	2059	1915	1269	937	753	5845	147	135	257
CD41	2	2902	2545	1822	1413	1162	4505	182	81	273
CD43	1	2094	1940	1289	950	760	5871	146	134	258
CD43	2	2949	2573	1851	1441	1187	4464	183	82	273
CD45	1	2036	1878	1255	930	748	6087	134	135	258
CD45	2	2885	2526	1821	1422	1174	4656	178	82	272
CD47	1	2051	1889	1268	942	759	6151	133	138	256
CD47	2	2895	2537	1833	1435	1188	4722	178	87	271
CD49	1	2029	1872	1257	936	756	6258	131	135	257
CD49	2	2854	2505	1811	1418	1174	4821	176	85	272
CD51	1	2015	1886	1244	917	735	5894	146	135	255
CD51	2	2854	2507	1788	1383	1136	4547	180	81	272
CD53	1	2130	1959	1312	972	779	5882	145	133	259
CD53	2	2987	2604	1884	1473	1217	4466	182	83	273
CD55	1	2002	1847	1233	915	736	6141	132	135	256
CD55	2	2867	2510	1810	1413	1167	4697	178	82	271
CD57	1	1973	1819	1220	910	735	6305	127	140	256
CD57	2	2821	2479	1787	1398	1158	4872	174	92	271
CD59	1	1948	1789	1205	902	730	6418	122	140	253
CD59	2	2774	2432	1757	1376	1142	4983	169	96	271

Appendix B-IV.1 (Continued)

Grid	Scenario	CHU	GDD0	GDD5	GDD8	GDD10	HDD18	FFD	REGROW	ENGROW
CD61	1	1920	1802	1184	873	701	6122	139	137	251
CD61	2	2762	2434	1727	1331	1091	4781	177	86	270
CD63	1	1934	1800	1188	875	701	6180	136	136	253
CD63	2	2786	2439	1739	1346	1106	4768	177	84	270
CD67	1	1861	1719	1146	853	689	6411	121	142	250
CD67	2	2727	2394	1714	1332	1099	4982	171	98	270
CD69	1	1891	1748	1164	863	695	6444	123	142	251
CD69	2	2743	2401	1719	1335	1100	5011	170	98	270
CD71	1	1788	1666	1101	815	656	6369	120	138	246
CD71	2	2639	2334	1648	1271	1043	5042	168	99	268
CD73	1	1999	1869	1226	891	705	6086	142	136	254
CD73	2	2868	2510	1780	1369	1116	4707	184	82	271
CD77	1	1863	1742	1143	836	664	6378	128	137	250
CD77	2	2733	2398	1698	1306	1066	4964	172	101	270
CD79	1	1906	1804	1169	837	650	6411	137	143	250
CD79	2	2779	2416	1707	1306	1058	4977	174	99	269
CD81	1	1813	1713	1119	825	663	6413	129	139	242
CD81	2	2619	2326	1631	1250	1021	5104	169	111	268
CD83	1	1898	1781	1166	852	679	6344	133	139	251
CD83	2	2745	2417	1705	1308	1067	4999	176	102	270
CD85	1	1896	1780	1166	854	681	6422	131	138	249
CD85	2	2730	2404	1697	1304	1065	5059	173	106	269
CD91	1	1716	1671	1058	749	579	6469	136	142	236
CD91	2	2577	2288	1577	1183	945	5150	171	106	268
CE11	1	2170	1996	1366	1034	845	6096	138	133	262
CE11	2	2967	2633	1930	1532	1283	4635	176	83	273
CE21	1	2149	1980	1350	1019	831	6111	138	133	261
CE21	2	2942	2602	1902	1505	1258	4659	175	85	273
CE31	1	2101	1938	1308	976	790	6236	139	137	257
CE31	2	2929	2582	1870	1467	1217	4773	180	85	273
CE41	1	2074	1909	1284	954	768	6284	134	138	257
CE41	2	2910	2551	1844	1444	1195	4812	178	89	272
CE51	1	2037	1868	1264	947	769	6369	127	138	255
CE51	2	2863	2517	1824	1432	1190	4902	175	94	272
CE61	1	2023	1869	1248	923	739	6386	136	140	254
CE61	2	2850	2492	1790	1394	1150	4920	175	96	270
CE71	1	1993	1867	1226	891	703	6387	140	142	252
CE71	2	2822	2460	1751	1351	1104	4937	175	97	270
DB15	1	1716	1655	1062	773	616	6372	129	139	239
DB15	2	2471	2197	1526	1157	938	5152	156	115	266
DB17	1	1816	1746	1118	804	634	6290	141	134	244
DB17	2	2623	2319	1615	1223	986	5070	169	110	268
DB19	1	1999	1877	1225	891	706	6150	149	131	253
DB19	2	2803	2458	1734	1329	1081	4942	177	109	270
DB25	1	1734	1674	1069	772	611	6433	138	145	240
DB25	2	2528	2250	1556	1175	946	5214	164	116	265
DB27	1	1697	1613	1047	775	624	6696	125	145	242
DB27	2	2463	2197	1528	1166	952	5484	159	127	265
DB29	1	1768	1677	1086	793	632	6482	133	145	243
DB29	2	2554	2260	1575	1199	975	5266	164	122	265
DC11	1	2043	1898	1258	930	749	6277	144	140	256
DC11	2	2834	2495	1775	1372	1126	5077	178	118	271
DC13	1	1954	1827	1200	882	706	6348	140	142	252
DC13	2	2758	2428	1714	1317	1075	5134	173	120	270
DC19	1	1762	1707	1083	763	588	6362	130	140	243
DC19	2	2630	2336	1609	1207	962	5083	174	102	265
DC21	1	1872	1782	1152	834	661	6475	143	144	249
DC21	2	2645	2336	1633	1243	1007	5259	167	122	267
DC23	1	1856	1753	1141	834	665	6494	134	144	249
DC23	2	2627	2322	1627	1242	1010	5281	165	122	268
DC31	1	1834	1734	1129	827	662	6755	135	138	245
DC31	2	2596	2302	1612	1232	1004	5554	161	122	266

Appendix B-IV.1 (Continued)

Grid	Scenario	CHU	GDD0	GDD5	GDD8	GDD10	HDD18	FFD	REGROW	ENGROW
DC33	1	1833	1736	1127	822	655	6727	138	138	247
DC33	2	2608	2308	1613	1231	1000	5525	163	118	265
DC51	1	1783	1718	1098	782	608	6941	133	144	238
DC51	2	2570	2276	1577	1190	955	5731	161	125	263
DC71	1	1663	1605	1026	733	571	7295	122	149	240
DC71	2	2443	2168	1499	1131	909	6072	150	133	260
DC73	1	1796	1685	1106	811	646	7285	123	145	242
DC73	2	2531	2237	1571	1205	984	6086	155	127	262
DC75	1	1943	1796	1196	884	708	7118	130	142	247
DC75	2	2666	2342	1663	1287	1056	5931	156	126	265
DC85	1	1595	1569	993	706	548	7350	117	151	229
DC85	2	2350	2102	1445	1083	867	6114	144	134	258
DD27	1	1757	1697	1088	776	604	6802	130	147	239
DD27	2	2552	2276	1575	1188	952	5520	162	127	263
DD29	1	1796	1723	1107	788	609	6755	132	146	240
DD29	2	2607	2307	1601	1210	970	5465	163	127	265
DD37	1	1878	1771	1161	848	673	6803	132	144	245
DD37	2	2648	2356	1651	1262	1025	5577	158	131	267
DD39	1	1926	1800	1195	881	705	6756	129	140	250
DD39	2	2688	2383	1686	1300	1065	5524	158	127	269
DD47	1	1880	1750	1166	866	696	6863	125	141	250
DD47	2	2642	2348	1661	1283	1053	5674	153	131	268
DD49	1	1803	1715	1116	808	636	6885	126	145	241
DD49	2	2572	2286	1594	1213	981	5661	151	133	268
DE31	1	1865	1746	1155	848	677	6765	126	142	248
DE31	2	2657	2360	1661	1276	1041	5520	157	128	268

Appendix B-V.1: Seeding dates by weather grid boxes for historical (1x; SN6) and doubled (2x; SN4 and SN5) atmospheric CO_2 concentrations.

	Grid	SN6	SN5	SN4	(SN5-SN6)	(SN4-SN6)
1	BC49	Jun 5	May 19	May 14	-17	-22
2	BC59	May 26	Apr 29	Apr 27	-27	-29
3	BC69	May 23	Apr 23	Apr 24	-30	-29
4	BC77	May 8	Apr 23	Apr 20	-15	-18
5	BC79	May 10	Apr 19	Apr 19	-21	-21
6	BC85	Jun 5	May 14	May 14	-22	-22
7	BC87	May 9	Apr 25	Apr 23	-14	-16
8	BC89	May 12	Apr 17	Apr 16	-25	-26
9	BC93	May 31	May 2	May 10	-29	-21
10	BC95	Jun 5	May 11	May 14	-25	-22
11	BC97	May 16	Apr 26	Apr 26	-20	-20
12	BC99	Apr 29	Apr 15	Apr 21	-14	-8
13	BD31	Apr 2	Apr 11	Apr 21	-16	-6
14	BD33	May 3	Apr 6	Apr 14	-27	-19
15	BD35	Apr 26	Mar 27	Apr 7	-30	-19
16	BD37	Apr 28	Mar 29	Apr 3	-30	-25
17	BD39	May 2	Apr 4	Apr 9	-28	-23
18	BD41	May 17	Apr 19	Apr 22	-28	-25
19	BD43	Apr 24	Mar 12	Mar 23	-43	-32
20	BD45	May 2	Apr 1	Apr 3	-31	-29
21	BD47	Apr 27	Apr 2	Apr 13	-25	-14
22	BD49	May 5	Apr 3	Apr 2	-32	-33
23	BD51	May 22	Apr 17	Apr 18	-35	-34
24	BD53	Apr 30	Mar 25	Apr 3	-36	-27
25	BD55	Apr 26	Apr 4	Apr 8	-22	-18
26	BD57	Apr 24	Apr 2	Apr 10	-22	-14
27	BD59	Apr 30	Apr 4	Apr 8	-26	-22
28	BD61	May 18	Apr 13	Apr 18	-35	-30
29	BD63	Apr 27	Apr 5	Apr 18	-22	-9
30	BD65	May 4	Apr 8	Apr 23	-26	-11
31	BD67	May 12	Apr 13	Apr 24	-29	-18
32	BD69	May 11	Apr 4	Apr 13	-37	-28
33	BD71	May 8	Apr 15	Apr 17	-23	-21
34	BD73	May 11	Apr 12	Apr 23	-29	-18
35	BD75	May 15	Apr 13	Apr 19	-32	-26
36	BD77	May 14	Apr 18	Apr 19	-26	-25
37	BD79	May 12	Apr 15	Apr 16	-27	-26
38	BD81	May 12	Apr 16	Apr 20	-26	-22
39	BD83	May 5	Apr 18	Apr 19	-17	-16
40	BD85	May 16	Apr 16	Apr 26	-30	-20
41	BD87	May 18	Apr 23	Apr 22	-25	-26
42	BD89	May 21	Apr 23	Apr 25	-28	-26
43	BD91	May 16	Apr 19	Apr 23	-27	-23

Appendix B-V.1 (Continued)

	Grid	SN6	SN5	SN4	(SN5-SN6)	(SN4-SN6)
44	BD93	May 16	Apr 19	Apr 23	-27	-23
45	BD95	May 18	Apr 25	Apr 23	-23	-25
46	BD97	May 19	Apr 22	Apr 24	-27	-25
47	BD99	May 20	Apr 19	Apr 22	-31	-28
48	BE31	May 16	Apr 8	Apr 15	-38	-31
49	BE41	May 18	Apr 7	Apr 13	-41	-35
50	BE51	May 2	Apr 2	Apr 4	-30	-28
51	BE61	May 12	Apr 15	Apr 8	-27	-34
52	BE71	May 13	Apr 12	Apr 18	-31	-25
53	BE81	May 21	Apr 20	Apr 19	-31	-32
54	BE91	May 19	Apr 26	Apr 23	-23	-26
55	CB39	Jun 2	May 10	May 13	-23	-20
56	CB47	May 19	May 12	May 3	-7	-16
57	CB49	May 22	May 10	May 21	-12	-1
58	CB77	May 14	Apr 26	May 5	-18	-9
59	CB79	May 16	Apr 30	May 1	-16	-15
60	CB85	May 21	May 1	May 13	-20	-8
61	CB87	May 21	Apr 30	May 2	-21	-19
62	CB89	May 19	May 4	May 8	-15	-11
63	CB95	May 26	May 6	May 9	-20	-17
64	CB97	May 22	May 2	May 9	-20	-13
65	CB99	May 13	May 2	May 9	-11	-4
66	CC15	Jun 6	Apr 21	Apr 19	-46	-48
67	CC17	May 15	Apr 22	Apr 19	-23	-26
68	CC19	May 1	Apr 19	Apr 21	-12	-10
69	CC21	May 29	May 3	May 8	-26	-21
70	CC23	May 27	Apr 28	May 4	-29	-23
71	CC25	May 15	Apr 25	Apr 22	-20	-23
72	CC27	May 6	Apr 18	Apr 21	-18	-15
73	CC29	May 12	Apr 16	Apr 21	-26	-21
74	CC31	May 26	Apr 28	May 4	-28	-22
75	CC33	May 9	Apr 17	Apr 21	-22	-18
76	CC35	May 20	Apr 24	Apr 24	-26	-26
77	CC37	May 23	Apr 23	Apr 24	-30	-29
78	CC39	May 19	Apr 17	Apr 18	-32	-31
79	CC41	May 23	Apr 22	Apr 27	-31	-26
80	CC43	May 15	Apr 23	Apr 22	-22	-23
81	CC45	May 17	Apr 26	Apr 27	-21	-20
82	CC47	May 22	Apr 23	Apr 26	-29	-26
83	CC49	May 18	Apr 22	Apr 26	-26	-22
84	CC51	May 28	Apr 18	Apr 21	-40	-37
85	CC53	May 14	Apr 27	Apr 23	-17	-21
86	CC55	May 27	Apr 27	May 6	-30	-21
87	CC57	May 26	Apr 25	May 3	-31	-23
88	CC59	May 20	Apr 22	Apr 27	-28	-23
89	CC65	May 27	May 3	May 9	-24	-18
90	CC67	May 23	Apr 27	May 9	-26	-14
91	CC69	May 21	Apr 24	May 3	-27	-18
92	CC77	Jun 2	Apr 30	May 8	-33	-25
93	CC79	May 30	Apr 29	Apr 28	-31	-32
94	CC87	Jun 1	May 2	May 2	-30	-30
95	CC89	May 26	May 6	May 3	-20	-23
96	CC97	May 23	May 1	May 2	-22	-21
97	CC99	May 25	May 4	May 3	-21	-22
98	CD11	May 18	Apr 19	Apr 21	-29	-27
99	CD13	May 22	Apr 22	Apr 28	-30	-24
100	CD15	May 22	Apr 23	Apr 25	-29	-27
101	CD17	May 25	Apr 25	Apr 27	-30	-28
102	CD19	May 26	Apr 21	Apr 23	-35	-33
103	CD21	May 23	Apr 24	Apr 23	-29	-30
104	CD23	May 24	Apr 25	May 1	-29	-23
105	CD25	May 22	Apr 26	Apr 29	-26	-23

Appendix B-V.1 (Continued)

	Grid	SN6	SN5	SN4	(SN5-SN6)	(SN4-SN6)
106	CD27	May 22	Apr 25	Apr 29	-27	-23
107	CD29	May 15	Apr 22	Apr 22	-23	-23
108	CD31	May 22	Apr 25	May 1	-27	-21
109	CD33	May 23	Apr 27	May 1	-26	-22
110	CD35	May 18	May 1	May 3	-17	-15
111	CD37	May 20	Apr 26	May 2	-24	-18
112	CD39	May 20	Apr 25	Apr 28	-25	-22
113	CD41	May 19	Apr 28	Apr 30	-21	-19
114	CD43	May 23	Apr 29	May 2	-24	-21
115	CD45	May 20	Apr 26	May 3	-24	-17
116	CD47	May 24	Apr 28	Apr 28	-26	-26
117	CD49	May 19	Apr 26	Apr 29	-23	-20
118	CD51	May 20	Apr 19	Apr 25	-31	-25
119	CD53	May 20	Apr 29	May 1	-21	-19
120	CD55	May 20	May 1	May 1	-19	-19
121	CD57	May 26	Apr 27	May 3	-29	-23
122	CD59	May 25	Apr 30	May 1	-25	-24
123	CD61	May 25	Apr 26	Apr 30	-29	-25
124	CD63	May 20	Apr 29	May 3	-21	-17
125	CD67	May 25	Apr 30	May 3	-25	-22
126	CD69	May 23	Apr 26	May 3	-27	-20
127	CD71	May 27	Apr 27	May 3	-30	-24
128	CD73	May 18	Apr 24	May 2	-24	-16
129	CD77	May 24	Apr 23	May 2	-31	-22
130	CD79	May 26	Apr 29	May 2	-27	-24
131	CD81	May 22	May 1	May 4	-21	-18
132	CD83	May 25	Apr 28	May 4	-27	-21
133	CD85	May 23	May 4	May 2	-19	-21
134	CD91	May 26	May 1	May 3	-25	-23
135	CE11	May 17	Apr 23	Apr 22	-24	-25
136	CE21	May 20	Apr 21	Apr 25	-29	-25
137	CE31	May 21	Apr 23	Apr 24	-28	-27
138	CE41	May 20	Apr 26	Apr 26	-24	-24
139	CE51	May 19	Apr 25	Apr 29	-24	-20
140	CE61	May 24	Apr 29	May 1	-25	-23
141	CE71	May 25	Apr 27	Apr 28	-28	-27
142	DB15	May 25	May 7	May 8	-18	-17
143	DB17	May 20	May 6	May 15	-14	-5
144	DB19	May 18	May 9	May 12	-9	-6
145	DB25	May 28	May 12	May 15	-16	-13
146	DB27	May 26	May 18	May 17	-8	-9
147	DB29	May 24	May 11	May 13	-13	-11
148	DC11	May 23	May 10	May 11	-13	-12
149	DC13	May 25	May 11	May 9	-14	-16
150	DC19	May 25	May 2	May 3	-23	-22
151	DC21	May 26	May 10	May 9	-16	-17
152	DC23	May 24	May 10	May 7	-14	-17
153	DC31	May 22	May 10	May 14	-12	-8
154	DC33	May 24	May 9	May 11	-15	-13
155	DC51	May 23	May 18	May 20	-5	-3
156	DC71	May 26	May 16	May 16	-10	-10
157	DC73	May 25	May 14	May 14	-11	-11
158	DC75	May 24	May 11	May 11	-13	-13
159	DC85	May 30	May 15	May 15	-15	-15
160	DD27	May 25	May 12	May 13	-13	-12
161	DD29	May 24	May 11	May 14	-13	-10
162	DD37	May 25	May 16	May 18	-9	-7
163	DD39	May 21	May 15	May 16	-6	-5
164	DD47	May 23	May 16	May 16	-7	-7
165	DD49	May 28	May 19	May 18	-9	-10
166	DE31	May 26	May 14	May 14	-12	-12

Appendix B-V.2a: Growth duration for canola by weather grid boxes for historical (1x; SN6) and doubled (2x; SN5 and SN4) atmospheric CO_2 concentrations.

Grid	SN6	SN5	SN4	(SN5-SN6)	(SN4-SN6)
BC49	98	88	89	-10	-9
BC59	97	98	98	1	1
BC69	100	97	96	-3	-4
BC79	95	96	95	1	0
BC89	96	96	95	0	-1
BC99	94	95	95	1	1
BD31	92	94	90	2	-2
BD33	96	88	84	-8	-12
BD35	94	87	81	-7	-13
BD37	92	83	78	-9	-14
BD39	90	80	77	-10	-13
BD41	98	93	91	-5	-7
BD43	94	90	85	-4	-9
BD45	93	81	78	-12	-15
BD47	91	79	74	-12	-17
BD49	88	79	78	-9	-10
BD51	99	96	95	-3	-4
BD53	96	87	82	-9	-14
BD55	94	79	76	-15	-18
BD57	92	79	74	-13	-18
BD59	87	77	73	-10	-14
BD61	99	95	92	-4	-7
BD63	95	84	78	-11	-17
BD65	92	79	72	-13	-20
BD67	87	76	71	-11	-16
BD69	84	78	74	-6	-10
BD71	97	90	88	-7	-9
BD73	95	82	77	-13	-18
BD75	89	78	75	-11	-14
BD77	86	75	74	-11	-12
BD79	87	76	75	-11	-12
BD81	99	89	86	-10	-13
BD83	96	81	79	-15	-17
BD85	87	77	73	-10	-14
BD87	88	75	75	-13	-13
BD89	87	76	75	-11	-12
BD91	99	88	85	-11	-14
BD93	93	80	77	-13	-16
BD95	91	76	77	-15	-14
BD97	92	78	77	-14	-15
BD99	92	80	78	-12	-14
BE31	84	80	77	-4	-7
BE41	92	86	83	-6	-9
BE51	89	80	77	-9	-12
BE61	82	74	75	-8	-7
BE71	81	73	71	-8	-10
BE81	84	74	75	-10	-9
BE91	87	74	75	-13	-12
CB77	97	95	92	-2	-5
CB79	98	89	88	-9	-10
CB87	100	87	86	-13	-14
CB89	100	83	82	-17	-18
CB97	100	86	84	-14	-16
CB99	99	81	79	-18	-20
CC17	99	94	94	-5	-5
CC19	93	94	92	1	-1
CC25	98	95	95	-3	-3
CC27	95	95	95	0	0
CC29	99	93	90	-6	-9

Appendix B-V.2a (Continued)

Grid	SN6	SN5	SN4	(SN5-SN6)	(SN4-SN6)
CC35	98	96	96	-2	-2
CC37	99	91	90	-8	-9
CC39	100	90	88	-10	-12
CC43	97	96	95	-1	-2
CC45	99	93	92	-6	-7
CC47	100	91	89	-9	-11
CC49	100	86	83	-14	-17
CC53	96	96	95	0	-1
CC55	100	93	90	-7	-10
CC57	101	90	87	-11	-14
CC59	100	85	82	-15	-18
CC65	100	91	89	-9	-11
CC67	100	89	85	-11	-15
CC69	100	84	81	-16	-19
CC77	99	94	91	-5	-8
CC79	100	88	88	-12	-12
CC87	98	94	94	-4	-4
CC89	100	87	88	-13	-12
CC97	100	86	85	-14	-15
CD11	99	86	84	-13	-15
CD13	96	82	79	-16	-19
CD15	94	79	77	-15	-17
CD17	91	77	76	-14	-15
CD19	91	79	78	-12	-13
CD21	99	83	83	-16	-16
CD23	97	80	78	-17	-19
CD25	92	76	74	-16	-18
CD27	91	76	74	-15	-17
CD29	94	78	78	-16	-16
CD31	98	82	79	-16	-19
CD33	95	78	76	-17	-19
CD35	94	74	74	-20	-20
CD37	93	76	74	-17	-19
CD39	95	78	76	-17	-19
CD41	97	77	77	-20	-20
CD43	95	75	74	-20	-21
CD45	96	76	73	-20	-23
CD47	94	75	75	-19	-19
CD49	96	77	75	-19	-21
CD51	98	82	79	-16	-19
CD53	94	73	72	-21	-22
CD55	97	74	73	-23	-24
CD57	96	76	74	-20	-22
CD59	96	76	76	-20	-20
CD61	99	81	79	-18	-20
CD63	99	78	76	-21	-23
CD67	99	78	77	-21	-22
CD69	98	80	77	-18	-21
CD71	100	83	81	-17	-19
CD73	98	80	77	-18	-21
CD77	100	83	79	-17	-21
CD79	98	81	80	-17	-18
CD81	100	83	82	-17	-18
CD83	99	82	80	-17	-19
CD85	100	80	80	-20	-20
CE11	90	77	76	-13	-14
CE21	90	78	75	-12	-15
CE31	92	78	76	-14	-16
CE41	93	77	76	-16	-17
CE51	94	77	75	-17	-19
CE61	95	77	77	-18	-18
CE71	97	80	80	-17	-17

Appendix B-V.2a (Continued)

Grid	SN6	SN5	SN4	(SN5-SN6)	(SN4-SN6)
DB15	100	86	86	-14	-14
DB17	99	84	81	-15	-18
DB19	98	78	77	-20	-21
DB25	100	83	82	-17	-18
DB27	100	82	82	-18	-18
DB29	100	83	82	-17	-18
DC11	96	76	76	-20	-20
DC13	98	78	78	-20	-20
DC21	99	81	81	-18	-18
DC23	99	81	82	-18	-17
DC31	99	81	80	-18	-19
DC33	99	82	81	-17	-18
DC71	99	83	82	-16	-17
DC73	99	80	80	-19	-19
DC75	95	77	77	-18	-18

Appendix B-V.2b: Growth duration for spring wheat by weather grid boxes for historical (1x; SN6) and doubled (2x; SN5 and SN4) atmospheric CO_2 concentrations.

Grid	SN6	SN5	SN4	(SN5-SN6)	(SN4-SN6)
BC49	107	91	92	-16	-15
BC59	108	105	105	-3	-3
BC69	108	107	107	-1	-1
BC79	107	107	106	0	-1
BC89	108	104	104	-4	-4
BC99	108	102	99	-6	-9
BD31	106	98	93	-8	-13
BD33	105	92	89	-13	-16
BD35	103	93	87	-10	-16
BD37	97	88	84	-9	-13
BD39	95	85	82	-10	-13
BD41	107	95	94	-12	-13
BD43	103	98	93	-5	-10
BD45	96	86	83	-10	-13
BD47	96	84	78	-12	-18
BD49	92	84	83	-8	-9
BD51	108	100	99	-8	-9
BD53	103	93	88	-10	-15
BD55	98	83	80	-15	-18
BD57	97	84	79	-13	-18
BD59	92	81	78	-11	-14
BD61	108	99	96	-9	-12
BD63	103	88	83	-15	-20
BD65	96	83	78	-13	-18
BD67	91	80	77	-11	-14
BD69	88	83	78	-5	-10
BD71	107	94	92	-13	-15
BD73	98	87	83	-11	-15
BD75	92	83	81	-9	-11
BD77	90	80	79	-10	-11
BD79	90	80	80	-10	-10
BD81	105	93	91	-12	-14
BD83	101	86	85	-15	-16
BD85	91	82	78	-9	-13
BD87	92	80	81	-12	-11
BD89	91	81	80	-10	-11
BD91	105	92	90	-13	-15
BD93	95	85	83	-10	-12
BD95	94	82	82	-12	-12
BD97	94	83	82	-11	-12
BD99	95	85	84	-10	-11
BE31	89	86	82	-3	-7
BE41	97	90	87	-7	-10
BE51	93	84	82	-9	-11
BE61	87	78	80	-9	-7
BE71	85	77	75	-8	-10
BE81	87	79	80	-8	-7
BE91	91	79	80	-12	-11
CB77	108	98	95	-10	-13
CB79	108	92	92	-16	-16
CB87	107	91	90	-16	-17
CB89	106	88	87	-18	-19
CB97	107	91	89	-16	-18
CB99	104	86	84	-18	-20
CC17	107	107	106	0	-1
CC19	108	98	97	-10	-11
CC25	109	107	107	-2	-2
CC27	107	103	102	-4	-5
CC29	108	98	95	-10	-13

Appendix B-V.2b (Continued)

Grid	SN6	SN5	SN4	(SN5-SN6)	(SN4-SN6)
CC35	108	103	103	-5	-5
CC37	107	95	95	-12	-12
CC39	106	95	94	-11	-12
CC43	109	102	102	-7	-7
CC45	108	97	96	-11	-12
CC47	108	96	94	-12	-14
CC49	104	91	89	-13	-15
CC53	108	101	102	-7	-6
CC55	108	97	93	-11	-15
CC57	108	94	91	-14	-17
CC59	103	90	88	-13	-15
CC65	108	94	92	-14	-16
CC67	107	93	89	-14	-18
CC69	104	90	86	-14	-18
CC77	108	97	94	-11	-14
CC79	107	92	92	-15	-15
CC87	108	97	97	-11	-11
CC89	108	91	92	-17	-16
CC97	106	90	90	-16	-16
CD11	103	91	90	-12	-13
CD13	100	87	85	-13	-15
CD15	96	84	83	-12	-13
CD17	94	82	81	-12	-13
CD19	94	84	83	-10	-11
CD21	103	88	89	-15	-14
CD23	100	86	83	-14	-17
CD25	94	81	80	-13	-14
CD27	94	81	80	-13	-14
CD29	97	84	83	-13	-14
CD31	102	87	84	-15	-18
CD33	99	83	82	-16	-17
CD35	97	80	80	-17	-17
CD37	96	81	80	-15	-16
CD39	97	83	82	-14	-15
CD41	99	83	83	-16	-16
CD43	98	80	80	-18	-18
CD45	98	81	80	-17	-18
CD47	97	81	81	-16	-16
CD49	98	82	82	-16	-16
CD51	101	88	85	-13	-16
CD53	96	79	78	-17	-18
CD55	99	80	80	-19	-19
CD57	99	82	80	-17	-19
CD59	99	82	81	-17	-18
CD61	102	86	85	-16	-17
CD63	102	83	82	-19	-20
CD67	102	83	83	-19	-19
CD69	101	85	83	-16	-18
CD71	105	88	86	-17	-19
CD73	101	86	83	-15	-18
CD77	103	88	84	-15	-19
CD79	102	86	85	-16	-17
CD81	105	88	87	-17	-18
CD83	103	87	85	-16	-18
CD85	103	85	85	-18	-18
CE11	93	81	81	-12	-12
CE21	93	83	81	-10	-12
CE31	95	83	82	-12	-13
CE41	96	82	82	-14	-14
CE51	97	83	81	-14	-16
CE61	98	83	82	-15	-16
CE71	100	85	85	-15	-15

Appendix B-V.2b (Continued)

Grid	SN6	SN5	SN4	(SN5-SN6)	(SN4-SN6)
DB15	107	90	89	-17	-18
DB17	106	88	86	-18	-20
DB19	101	83	83	-18	-18
DB25	107	88	87	-19	-20
DB27	107	87	87	-20	-20
DB29	106	87	87	-19	-19
DC11	199	82	82	-17	-17
DC13	101	83	84	-18	-17
DC21	104	86	86	-18	-18
DC23	104	86	87	-18	-17
DC31	104	86	85	-18	-19
DC33	104	87	86	-17	-18
DC71	107	88	88	-19	-19
DC73	104	85	85	-19	-19
DC75	99	83	83	-16	-16

Appendix B-V.2c: Growth duration for winter wheat by weather grid boxes for historical (1x; SN6) and doubled (2x; SN5 and SN4) atmospheric CO_2 concentrations.

Grid	SN6	SN5	SN4	(SN5-SN6)	(SN4-SN6)
BC49	177	157	159	-20	-18
BC59	177	161	162	-16	-15
BC69	197	166	167	-31	-30
BC79	184	162	162	-22	-22
BC89	170	158	159	-12	-11
BC99	169	152	153	-17	-16
BD31	167	146	147	-21	-20
BD33	156	135	139	-21	-17
BD35	151	133	135	-18	-16
BD37	145	131	131	-14	-14
BD39	143	131	134	-12	-9
BD41	169	147	147	-22	-22
BD43	152	130	129	-22	-23
BD45	149	136	131	-13	-18
BD47	143	136	130	-7	-13
BD49	140	136	131	-4	-9
BD51	176	156	149	-20	-27
BD53	153	139	132	-14	-21
BD55	144	135	130	-9	-14
BD57	139	135	129	-4	-10
BD59	135	133	128	-2	-7
BD61	167	154	146	-13	-21
BD63	146	141	133	-5	-13
BD65	139	137	131	-2	-8
BD67	137	136	130	-1	-7
BD69	136	135	129	-1	-7
BD71	157	150	143	-7	-14
BD73	142	142	136	0	-6
BD75	138	139	133	1	-5
BD77	132	136	130	4	-2
BD79	130	136	128	6	-2
BD81	154	153	142	-1	-12
BD83	141	145	137	4	-4
BD85	136	139	131	3	-5
BD87	132	137	129	5	-3
BD89	131	136	127	5	-4
BD91	150	151	143	1	-7
BD93	139	143	135	4	-4
BD95	137	142	134	5	-3
BD97	134	139	129	5	-5
BD99	133	136	126	3	-7
BE31	133	139	133	6	0
BE41	146	143	138	-3	-8
BE51	137	135	130	-2	-7
BE61	131	136	130	5	-1
BE71	128	132	125	4	-3
BE81	129	135	127	6	-2
BE91	130	135	126	5	-4
CB77	173	151	142	-22	-31
CB79	158	148	139	-10	-19
CB87	155	147	137	-8	-18
CB89	149	144	135	-5	-14
CB97	155	146	137	-9	-18
CB99	144	141	132	-3	-12
CC17	177	174	166	-3	-11
CC19	163	157	149	-6	-14
CC25	161	178	169	17	8
CC27	176	162	154	-14	-22
CC29	158	153	145	-5	-13

Appendix B-V.2c (Continued)

Grid	SN6	SN5	SN4	(SN5-SN6)	(SN4-SN6)
CC35	181	162	153	-19	-28
CC37	157	153	144	-4	-13
CC39	156	152	144	-4	-12
CC43	170	162	154	-8	-16
CC45	164	154	144	-10	-20
CC47	158	150	139	-8	-19
CC49	149	147	138	-2	-11
CC53	180	161	152	-19	-28
CC55	166	154	143	-12	-23
CC57	157	148	138	-9	-19
CC59	147	144	135	-3	-12
CC65	166	153	143	-13	-23
CC67	157	148	139	-9	-18
CC69	148	142	132	-6	-16
CC77	167	153	142	-14	-25
CC79	156	147	136	-9	-20
CC87	170	151	142	-19	-28
CC89	159	147	137	-12	-22
CC97	150	144	134	-6	-16
CD11	146	146	137	0	-9
CD13	143	145	137	2	-6
CD15	138	142	133	4	-5
CD17	135	140	130	5	-5
CD19	134	138	129	4	-5
CD21	147	147	138	0	-9
CD23	143	144	135	1	-8
CD25	137	141	133	4	-4
CD27	135	139	130	4	-5
CD29	134	138	129	4	-5
CD31	145	145	136	0	-9
CD33	141	143	134	2	-7
CD35	137	140	130	3	-7
CD37	134	137	128	3	-6
CD39	135	137	127	2	-8
CD41	142	143	133	1	-9
CD43	140	139	131	-1	-9
CD45	137	137	127	0	-10
CD47	135	136	126	1	-9
CD49	135	136	125	1	-10
CD51	143	143	133	0	-10
CD53	138	137	128	-1	-10
CD55	136	135	125	-1	-11
CD57	136	134	124	-2	-12
CD59	136	134	123	-2	-13
CD61	144	141	131	-3	-13
CD63	141	138	128	-3	-13
CD67	140	137	126	-3	-14
CD69	139	135	126	-4	-13
CD71	146	141	131	-5	-15
CD73	141	139	129	-2	-12
CD77	143	139	129	-4	-14
CD79	141	138	128	-3	-13
CD81	148	142	132	-6	-16
CD83	143	140	130	-3	-13
CD85	143	139	129	-4	-14
CE11	130	136	127	6	-3
CE21	131	137	127	6	-4
CE31	132	136	125	4	-7
CE41	132	135	124	3	-8
CE51	132	134	124	2	-8
CE61	136	136	126	0	-10
CE71	138	137	128	-1	-10

Appendix B-V.2c (Continued)

Grid	SN6	SN5	SN4	(SN5-SN6)	(SN4-SN6)
DB15	155	145	135	-10	-20
DB17	150	144	135	-6	-15
DB19	142	140	131	-2	-11
DB25	150	144	134	-6	-16
DB27	150	141	131	-9	-19
DB29	147	142	132	-5	-15
DC11	137	138	128	1	-9
DC13	139	140	129	1	-10
DC21	143	140	129	-3	-14
DC23	142	141	130	-1	-12
DC31	141	137	125	-4	-16
DC33	141	137	126	-4	-15
DC71	148	134	123	-14	-25
DC73	141	131	118	-10	-23
DC75	133	128	116	-5	-17

Appendix B-V.2d: Growth duration for corn by weather grid boxes for historical (1x; SN6) and doubled (2x; SN5 and SN4) atmospheric CO_2 concentrations. 0 represents grid boxes without sufficient heat for corn to growth under current climate.

Grid	SN6	SN5	SN4	(SN5-SN6)	(SN4-SN6)
BC49	0	123	125	0	0
BC89	0	133	133	0	0
BC99	0	126	124	0	0
BD31	0	113	109	0	0
BD33	0	104	100	0	0
BD35	0	101	96	0	0
BD37	115	94	91	-21	-24
BD39	113	93	90	-20	-23
BD41	0	113	111	0	0
BD43	0	105	97	0	0
BD45	121	94	91	-27	-30
BD47	113	91	86	-22	-27
BD49	112	92	90	-20	-22
BD51	0	122	120	0	0
BD53	0	102	97	0	0
BD55	120	92	89	-28	-31
BD57	114	91	87	-23	-27
BD59	104	89	86	-15	-18
BD71	0	108	107	0	0
BD73	0	98	93	0	0
BD75	125	94	90	-31	-35
BD77	118	90	88	-28	-30
BD79	116	90	88	-26	-28
BD81	0	107	105	0	0
BD83	0	97	96	0	0
BD85	121	91	87	-30	-34
BD87	0	91	90	0	0
BD89	0	91	90	0	0
BD91	0	107	105	0	0
BD93	0	96	94	0	0
BD95	0	92	92	0	0
BD97	0	94	93	0	0
BD99	0	96	94	0	0
BE31	112	93	89	-19	-23
BE41	0	101	96	0	0
BE51	111	92	90	-19	-21
BE61	105	87	87	-18	-18
BE71	98	86	83	-12	-15
BE81	116	87	89	-29	-27
BE91	0	88	90	0	0
CB77	0	132	131	0	0
CB79	0	116	116	0	0
CB87	0	111	111	0	0
CB89	0	106	105	0	0
CB97	0	113	112	0	0
CB99	0	102	100	0	0
CC19	0	118	116	0	0
CC27	0	133	132	0	0
CC29	0	115	113	0	0
CC37	0	113	113	0	0
CC39	0	110	110	0	0
CC45	0	124	123	0	0
CC47	0	115	114	0	0
CC49	0	105	103	0	0
CC55	0	126	125	0	0
CC57	0	114	112	0	0
CC59	0	104	103	0	0
CC65	0	124	125	0	0

Appendix B-V.2d (Continued)

Grid	SN6	SN5	SN4	(SN5-SN6)	(SN4-SN6)
CC67	0	115	113	0	0
CC69	0	105	102	0	0
CC77	0	129	129	0	0
CC79	0	112	112	0	0
CC87	0	130	131	0	0
CC89	0	116	115	0	0
CC97	0	109	108	0	0
CD11	0	104	103	0	0
CD13	0	101	99	0	0
CD15	0	96	94	0	0
CD17	0	94	93	0	0
CD19	0	96	94	0	0
CD21	0	103	103	0	0
CD23	0	98	97	0	0
CD25	0	92	91	0	0
CD27	0	92	91	0	0
CD29	0	95	94	0	0
CD31	0	100	98	0	0
CD33	0	96	94	0	0
CD35	0	91	91	0	0
CD37	0	92	91	0	0
CD39	0	94	93	0	0
CD41	0	96	95	0	0
CD43	0	93	92	0	0
CD45	0	93	92	0	0
CD47	0	92	92	0	0
CD49	0	94	93	0	0
CD51	0	100	97	0	0
CD53	0	90	90	0	0
CD55	0	91	91	0	0
CD57	0	94	92	0	0
CD59	0	95	95	0	0
CD61	0	101	100	0	0
CD63	0	96	96	0	0
CD67	0	98	97	0	0
BD61	0	117	115	0	0
BD63	0	99	93	0	0
BD67	90	90	85	0	-5
BD69	92	92	87	0	-5
BD65	93	93	87	0	-6

Appendix B-VI.1a: Dryland canola yields (g/m^2) by weather grid points for historical (1x; SN6) and doubled (2x; SN5 and SN4) atmospheric CO_2 concentrations.

Grid	SN6	SN5	SN4	SN5/SN6	SN4/SN6
BC49	131	235	216	1.8	1.65
BC59	73	222	223	3.02	3.05
BC69	59	209	209	3.51	3.52
BC79	55	212	204	3.8	3.66
BC89	129	288	283	2.23	2 19
BC99	119	278	280	2.33	2.35
BD31	113	276	281	2.44	2.48
BD33	211	305	312	1.44	1.48
BD35	151	234	283	1.55	1.88
BD37	128	153	280	1.2	2.18
BD39	121	148	277	1.23	2.29
BD41	181	289	283	1.59	1.56
BD43	169	213	268	1.26	1.58
BD45	157	173	280	1.1	1.78
BD47	136	154	276	1.13	2.03
BD49	116	138	224	1.19	1.92
BD51	150	291	299	1.94	1.99
BD53	153	207	260	1.35	1.69
BD55	140	152	277	1.09	1.97
BD57	123	135	255	1.1	2.07
BD59	108	125	199	1.15	1.83
BD61	190	303	289	1.59	1.52
BD63	183	251	276	1.37	1.5
BD65	140	151	297	1.08	2.13
BD67	130	147	255	1.13	1.96
BD69	104	122	223	1.17	2.13
BD71	220	342	323	1.55	1.47
BD73	199	256	288	1.29	1.45
BD75	139	154	287	1.11	2.06
BD77	95	112	135	1.17	1.41
BD79	111	129	260	1.16	2.33
BD81	252	340	314	1.35	1.25
BD83	209	242	277	1.15	1.32
BD85	182	195	292	1.07	1.6
BD87	121	128	264	1.06	2.18
BD89	114	127	265	1.12	2.33
BD91	255	302	302	1.19	1.18
BD93	237	255	294	1.08	1.24
BD95	216	226	281	1.04	1.3
BD97	172	178	267	1.03	1.55
BD99	142	146	256	1.03	1.81
BE31	110	146	272	1.32	2.46
BE41	170	245	287	1.44	1.68
BE51	122	138	235	1.13	1.92
BE61	97	105	222	1.09	2.29
BE71	101	110	199	1.09	1.97
BE81	122	133	259	1.09	2.12
BE91	141	154	253	1.09	1.79
CB77	124	271	261	2.17	2.1
CB79	168	251	275	1.49	1.63
CB87	199	279	265	1.4	1.34
CB89	215	276	263	1.28	1.22
CB97	201	281	285	1.4	1.41
CB99	238	283	274	1.19	1.15
CC17	66	210	206	3.19	3.13
CC19	155	291	271	1.88	1.75
CC25	51	177	169	3.44	3.28
CC27	126	253	260	2.01	2.06
CC29	222	294	292	1.32	1.31

Appendix B-VI.1a (Continued)

Grid	SN6	SN5	SN4	SN5/SN6	SN4/SN6
CC35	126	260	251	2.06	1.99
CC37	189	266	255	1.41	1.35
CC39	234	316	297	1.35	1.27
CC43	133	262	221	1.96	1.66
CC45	182	298	240	1.63	1.31
CC47	199	278	265	1.4	1.33
CC49	242	288	278	1.19	1.15
CC53	127	285	238	2.23	1.87
CC55	183	311	269	1.69	1.47
CC57	232	310	274	1.34	1.18
CC59	261	291	265	1.12	1.01
CC65	164	267	266	1.63	1.62
CC67	210	293	274	1.4	1.31
CC69	245	274	274	1.12	1.12
CC77	148	289	238	1.95	1.61
CC79	225	336	268	1.49	1.19
CC87	144	237	257	1.64	1.78
CC89	166	280	228	1.69	1.38
CC97	214	276	253	1.29	1.18
CD11	268	306	296	1.14	1.1
CD13	246	301	293	1.22	1.19
CD15	264	278	279	1.05	1.06
CD17	236	242	271	1.03	1.15
CD19	206	212	280	1.03	1.36
CD21	263	297	286	1.13	1.09
CD23	251	302	300	1.2	1.19
CD25	267	291	288	1.09	1.08
CD27	265	304	301	1.15	1.14
CD29	231	212	243	0.92	1.06
CD31	262	290	270	1.11	1.03
CD33	256	294	292	1.15	1.14
CD35	253	276	278	1.09	1.1
CD37	278	300	296	1.08	1.06
CD39	262	288	303	1.1	1.16
CD41	280	298	295	1.06	1.05
CD43	270	292	288	1.08	1.07
CD45	253	282	292	1.11	1.15
CD47	269	275	274	1.02	1.02
CD49	271	302	299	1.11	1.1
CD51	274	298	289	1.09	1.05
CD53	282	289	304	1.02	1.08
CD55	276	297	297	1.07	1.08
CD57	206	198	235	0.96	1.14
CD59	262	305	286	1.16	1.09
CD61	268	308	304	1.15	1.14
CD63	267	283	285	1.06	1.07
CD67	249	300	283	1.21	1.14
CD69	206	186	239	0.91	1.16
CD71	219	277	276	1.27	1.26
CD73	222	225	247	1.02	1.11
CD77	253	284	279	1.12	1.1
CD79	284	298	284	1.05	1
CD81	242	281	282	1.16	1.17
CD83	251	254	238	1.01	0.95
CD85	222	256	247	1.15	1.11
CE11	199	205	258	1.03	1.3
CE21	254	272	282	1.07	1.11
CE31	267	290	285	1.09	1.07
CE41	264	298	302	1.13	1.14
CE51	268	295	267	1.1	0.99
CE61	277	283	275	1.02	0.99
CE71	239	255	271	1.07	1.13

Appendix B-VI.1a (Continued)

Grid	SN6	SN5	SN4	SN5/SN6	SN4/SN6
DB15	209	279	258	1.34	1.23
DB17	232	280	261	1.21	1.13
DB19	247	281	273	1.14	1.11
DB25	220	285	280	1.3	1.27
DB27	219	332	304	1.52	1.39
DB29	225	289	291	1.28	1.29
DC11	226	267	245	1.19	1.09
DC13	249	302	272	1.21	1.09
DC21	229	289	252	1.26	1.1
DC23	237	303	298	1.28	1.25
DC31	231	277	286	1.2	1.24
DC33	260	331	275	1.27	1.06
DC71	176	250	237	1.42	1.35
DC73	167	188	203	1.12	1.21
DC75	204	247	233	1.21	1.14

Appendix B-VI.1b: Dryland spring wheat yields (g/m^2) by weather grid points for historical (1x; SN6) and doubled (2x; SN5 and SN4) atmospheric CO_2 concentrations.

Grid	SN6	SN5	SN4	SN5/SN6	SN4/SN6
BC49	132	168	166	1.27	1.26
BC59	104	159	157	1.52	1.50
BC69	89	152	150	1.72	1.69
BC79	82	149	146	1.81	1.78
BC89	119	171	171	1.43	1.43
BC99	110	154	155	1.40	1.41
BD31	125	175	166	1.40	1.33
BD33	147	199	192	1.35	1.30
BD35	122	170	174	1.39	1.42
BD37	111	151	178	1.35	1.59
BD39	110	153	182	1.40	1.66
BD41	135	182	181	1.35	1.34
BD43	124	163	169	1.31	1.36
BD45	113	154	170	1.36	1.50
BD47	113	149	175	1.31	1.54
BD49	109	145	180	1.33	1.65
BD51	129	181	180	1.40	1.39
BD53	119	154	162	1.29	1.36
BD55	111	144	177	1.30	1.59
BD57	94	113	135	1.20	1.44
BD59	101	134	179	1.33	1.77
BD61	139	192	191	1.38	1.37
BD63	126	162	167	1.29	1.33
BD65	112	156	182	1.40	1.63
BD67	99	135	156	1.37	1.57
BD69	92	123	169	1.34	1.83
BD71	148	203	206	1.37	1.40
BD73	123	157	165	1.27	1.34
BD75	104	148	169	1.42	1.62
BD77	84	109	118	1.30	1.42
BD79	93	118	153	1.27	1.65
BD81	154	202	203	1.31	1.31
BD83	126	158	165	1.25	1.31
BD85	144	191	197	1.33	1.37
BD87	103	121	155	1.18	1.50
BD89	97	116	153	1.20	1.58
BD91	145	184	185	1.27	1.27
BD93	150	192	195	1.28	1.30
BD95	142	186	193	1.30	1.35
BD97	120	147	163	1.22	1.35
BD99	107	123	151	1.14	1.40
BE31	99	140	175	1.42	1.77
BE41	115	154	168	1.34	1.46
BE51	107	141	181	1.32	1.69
BE61	89	108	171	1.21	1.92
BE71	92	110	153	1.20	1.66
BE81	104	126	164	1.21	1.58
BE91	108	131	154	1.21	1.42
CB77	112	145	144	1.30	1.29
CB79	121	145	142	1.20	1.18
CB87	133	167	165	1.25	1.24
CB89	137	170	168	1.24	1.23
CB97	141	183	182	1.29	1.29
CB99	140	175	172	1.25	1.23
CC17	81	133	132	1.64	1.63
CC19	115	150	152	1.30	1.31
CC25	70	120	118	1.71	1.68
CC27	105	139	139	1.31	1.32
CC29	123	150	154	1.22	1.24

Appendix B-VI.1b (Continued)

Grid	SN6	SN5	SN4	SN5/SN6	SN4/SN6
CC35	106	139	141	1.31	1.33
CC37	121	143	143	1.18	1.18
CC39	129	155	155	1.19	1.20
CC43	114	147	146	1.29	1.29
CC45	122	149	148	1.22	1.22
CC47	126	150	151	1.19	1.20
CC49	130	153	155	1.18	1.19
CC53	111	146	145	1.31	1.31
CC55	119	146	147	1.22	1.23
CC57	124	148	150	1.20	1.20
CC59	127	149	151	1.17	1.19
CC65	118	144	146	1.22	1.23
CC67	124	148	149	1.20	1.20
CC69	126	147	151	1.16	1.19
CC77	114	145	147	1.28	1.29
CC79	123	149	150	1.21	1.22
CC87	108	138	139	1.27	1.28
CC89	121	148	148	1.22	1.22
CC97	120	140	140	1.17	1.17
CD11	144	183	184	1.26	1.28
CD13	145	185	188	1.27	1.30
CD15	132	164	169	1.24	1.27
CD17	131	162	168	1.24	1.29
CD19	128	159	171	1.23	1.33
CD21	144	180	181	1.25	1.26
CD23	147	187	190	1.27	1.29
CD25	151	195	200	1.29	1.33
CD27	155	203	207	1.31	1.34
CD29	130	154	159	1.18	1.22
CD31	136	164	168	1.21	1.24
CD33	170	223	221	1.31	1.30
CD35	150	193	192	1.28	1.28
CD37	141	178	185	1.26	1.31
CD39	145	188	195	1.30	1.35
CD41	147	183	187	1.25	1.27
CD43	152	194	194	1.28	1.27
CD45	160	214	212	1.33	1.32
CD47	149	192	191	1.28	1.28
CD49	145	183	188	1.27	1.30
CD51	140	167	169	1.19	1.21
CD53	158	207	210	1.32	1.33
CD55	166	230	228	1.38	1.37
CD57	148	183	196	1.24	1.33
CD59	138	175	180	1.26	1.30
CD61	139	168	173	1.21	1.25
CD63	129	155	161	1.21	1.25
CD67	127	152	157	1.20	1.24
CD69	122	140	146	1.15	1.19
CD71	123	143	145	1.17	1.18
CD73	122	137	143	1.12	1.17
CD77	122	141	144	1.15	1.18
CD79	122	141	146	1.15	1.20
CD81	121	143	144	1.18	1.18
CD83	123	143	145	1.16	1.18
CD85	123	142	144	1.16	1.17
CE11	123	144	151	1.17	1.22
CE21	125	151	161	1.21	1.28
CE31	144	189	195	1.31	1.35
CE41	153	198	200	1.29	1.30
CE51	132	162	167	1.23	1.27
CE61	130	157	162	1.20	1.24
CE71	124	142	145	1.15	1.17

Appendix B-VI.1b (Continued)

Grid	SN6	SN5	SN4	SN5/SN6	SN4/SN6
DB15	118	143	144	1.21	1.21
DB17	122	146	147	1.19	1.20
DB19	140	175	174	1.25	1.24
DB25	127	157	158	1.24	1.25
DB27	126	156	158	1.24	1.25
DB29	135	170	171	1.26	1.27
DC11	122	143	144	1.17	1.18
DC13	130	157	161	1.20	1.24
DC21	131	160	162	1.23	1.24
DC23	143	177	183	1.23	1.27
DC31	138	171	174	1.24	1.26
DC33	151	188	193	1.25	1.28
DC71	118	141	142	1.20	1.21
DC73	113	133	136	1.17	1.20
DC75	109	125	129	1.14	1.19

Appendix B-VI.1c: Dryland corn yields (g/m^2) by weather grid points for historical (1x; SN6) and doubled (2x; SN5 and SN4) atmospheric CO_2 concentrations. 0. represents grid boxes without sufficient heat for corn to growth under current climate.

Grid	SN6	SN5	5N4	SN5/SN6	SN4/SN6
BC49	0	437	473	0	0
BC89	0	595	725	0	0
BC99	0	653	742	0	0
BD31	0	427	458	0	0
BD33	0	531	645	0	0
BD35	0	363	504	0	0
BD37	181	241	455	1.33	2.51
BD39	178	230	427	1.29	2.39
BD41	0	448	593	0	0
BD43	0	355	519	0	0
BD45	244	277	442	1.13	1.81
BD47	198	231	438	1.17	2.21
BD49	179	221	415	1.24	2.32
BD51	0	460	588	0	0
BD53	0	318	429	0	0
BD55	205	232	442	1.13	2.15
BD57	181	206	356	1.14	1.96
BD59	148	192	359	1.29	2.42
BD71	0	400	640	0	0
BD73	0	305	509	0	0
BD75	211	241	473	1.14	2.24
BD77	181	194	231	1.07	1.28
BD79	159	197	337	1.24	2.12
BD81	0	479	681	0	0
BD83	0	348	543	0	0
BD85	299	303	539	1.01	1.80
BD87	0	215	371	0	0
BD89	0	208	357	0	0
BD91	0	564	719	0	0
BD93	0	405	605	0	0
BD95	0	342	573	0	0
BD97	0	284	490	0	0
BD99	0	246	403	0	0
BE31	157	219	395	1.39	2.51
BE41	0	362	558	0	0
BE51	169	218	414	1.29	2.45
BE61	130	171	331	1.32	2.55
BE71	148	161	303	1.08	2.04
BE81	192	205	350	1.07	1.82
BE91	0	237	400	0	0
CB77	0	743	760	0	0
CB79	0	619	660	0	0
CB87	0	612	654	0	0
CB89	0	622	673	0	0
CB97	0	591	685	0	0
CB99	0	546	656	0	0
CC19	0	750	820	0	0
CC27	0	724	788	0	0
CC29	0	778	878	0	0
CC37	0	688	748	0	0
CC39	0	795	874	0	0
CC45	0	809	845	0	0
CC47	0	810	859	0	0
CC49	0	717	815	0	0
CC55	0	796	836	0	0
CC57	0	806	865	0	0
CC59	0	721	839	0	0
CC65	0	687	740	0	0

Appendix B-VI.1c (Continued)

Grid	SN6	SN5	SN4	SN5/SN6	SN4/SN6
CC67	0	824	864	0	0
CC69	0	629	729	0	0
CC77	0	851	863	0	0
CC79	0	820	879	0	0
CC87	0	810	844	0	0
CC89	0	839	866	0	0
CC97	0	738	800	0	0
CD11	0	594	778	0	0
CD13	0	483	717	0	0
CD15	0	408	628	0	0
CD17	0	365	591	0	0
CD19	0	315	578	0	0
CD21	0	641	796	0	0
CD23	0	531	766	0	0
CD25	0	421	705	0	0
CD27	0	446	723	0	0
CD29	0	390	503	0	0
CD31	0	664	821	0	0
CD33	0	599	754	0	0
CD35	0	502	707	0	0
CD37	0	419	727	0	0
CD39	0	449	716	0	0
CD41	0	642	833	0	0
CD43	0	555	770	0	0
CD45	0	511	750	0	0
CD47	0	497	716	0	0
CD49	0	464	733	0	0
CD51	0	620	782	0	0
CD53	0	492	777	0	0
CD55	0	507	796	0	0
CD57	0	466	599	0	0
CD59	0	496	759	0	0
CD61	0	637	838	0	0
CD63	0	579	832	0	0
CD67	0	544	800	0	0
BD61	0	452	593	0	0
BD63	0	320	486	0	0
BD67	223	229	395	1.02	1.77
BD69	166	184	350	1.11	2.10
BD65	212	228	443	1.07	2.08

Appendix B-VI.1d: Dryland crested wheatgrass yields (g/m^2) by weather grid boxes for historical (1x; SN6) and doubled (2x; SN4 and SN5) atmospheric CO_2 concentrations.

Grid	SN6	SN5	SN4	SN5/SN6	SN4/SN6
BC49	350	256	306	0.73	0.88
BC59	221	672	688	3.04	3.12
BC69	153	625	632	4.07	4.11
BC79	151	625	624	4.14	4.14
BC89	353	885	898	2.51	2.54
BC99	350	890	869	2.54	2.48
BD31	445	468	356	1.05	0.80
BD33	505	581	419	1.15	0.83
BD35	413	536	378	1.30	0.91
BD37	371	688	644	1.85	1.74
BD39	262	436	444	1.66	1.69
BD41	455	574	564	1.26	1.24
BD43	501	753	717	1.50	1.43
BD45	369	592	585	1.61	1.58
BD47	375	578	490	1.54	1.31
BD49	213	364	429	1.71	2.01
BD51	394	648	646	1.64	1.64
BD53	391	473	387	1.21	0.99
BD55	434	550	569	1.27	1.31
BD57	343	348	348	1.01	1.01
BD59	201	281	341	1.40	1.69
BD61	490	708	674	1.45	1.38
BD63	495	459	326	0.93	0.66
BD65	329	384	317	1.17	0.97
BD67	182	260	236	1.42	1.30
BD69	149	380	355	2.55	2.38
BD71	573	694	718	1.21	1.25
BD73	359	400	363	1.12	1.01
BD75	268	417	426	1.56	1.59
BD77	80	88	101	1.11	1.26
BD79	169	202	271	1.20	1.60
BD81	591	768	760	1.30	1.29
BD83	452	396	436	0.87	0.96
BD85	270	298	278	1.10	1.03
BD87	212	191	246	0.90	1.16
BD89	190	221	289	1.16	1.52
BD91	551	742	766	1.35	1.39
BD93	387	466	503	1.20	1.30
BD95	317	279	447	0.88	1.41
BD97	312	297	387	0.95	1.24
BD99	267	271	330	1.02	1.24
BE31	107	287	288	2.68	2.69
BE41	312	643	627	2.06	2.01
BE51	233	359	373	1.54	1.60
BE61	153	296	439	1.93	2.86
BE71	108	198	206	1.84	1.91
BE81	182	252	301	1.38	1.66
BE91	201	243	308	1.21	1.53
CB77	341	818	709	2.40	2.08
CB79	424	554	594	1.31	1.40
CB87	429	586	604	1.36	1.41
CB89	457	493	488	1.08	1.07
CB97	423	632	561	1.50	1.33
CB99	484	438	440	0.90	0.91
CC17	154	668	619	4.33	4.01
CC19	463	883	896	1.91	1.94
CC25	95	615	546	6.44	5.72
CC27	360	891	874	2.47	2.42
CC29	554	949	941	1.71	1.70

Appendix B-VI.1d (Continued)

Grid	SN6	SN5	SN4	SN5/SN6	SN4/SN6
CC35	329	958	952	2.91	2.89
CC37	418	696	765	1.66	1.83
CC39	557	944	957	1.70	1.72
CC43	375	971	946	2.59	2.52
CC45	474	906	900	1.91	1.90
CC47	510	917	907	1.80	1.78
CC49	523	676	718	1.29	1.37
CC53	348	948	948	2.72	2.73
CC55	409	898	856	2.19	2.09
CC57	474	913	877	1.92	1.85
CC59	546	793	833	1.45	1.52
CC65	364	710	713	1.95	1.96
CC67	487	882	829	1.81	1.70
CC69	457	560	630	1.22	1.38
CC77	357	977	916	2.74	2.57
CC79	450	909	967	2.02	2.15
CC87	328	905	883	2.76	2.69
CC89	446	815	866	1.83	1.94
CC97	476	709	746	1.49	1.57
CD11	518	775	817	1.50	1.58
CD13	451	579	645	1.28	1.43
CD15	361	468	539	1.30	1.49
CD17	303	344	427	1.14	1.41
CD19	310	405	496	1.30	1.60
CD21	508	730	791	1.44	1.56
CD23	460	658	725	1.43	1.57
CD25	373	552	633	1.48	1.70
CD27	372	477	575	1.28	1.54
CD29	328	313	413	0.95	1.26
CD31	516	687	721	1.33	1.40
CD33	444	553	610	1.25	1.38
CD35	400	400	500	1	1.25
CD37	412	526	622	1.28	1.51
CD39	407	503	571	1.24	1.40
CD41	557	647	710	1.16	1.28
CD43	457	528	638	1.15	1.39
CD45	436	439	550	1.01	1.26
CD47	390	432	567	1.11	1.46
CD49	464	507	610	1.09	1.32
CD51	510	680	716	1.33	1.40
CD53	458	550	676	1.20	1.48
CD55	475	531	688	1.12	1.45
CD57	318	291	442	0.92	1.39
CD59	442	583	716	1.32	1.62
CD61	490	691	775	1.41	1.58
CD63	520	642	776	1.23	1.49
CD67	481	565	726	1.18	1.51
CD69	349	306	409	0.88	1.17
CD71	466	709	718	1.52	1.54
CD73	407	425	584	1.05	1.44
CD77	496	633	724	1.28	1.46
CD79	467	641	765	1.37	1.64
CD81	495	701	778	1.42	1.57
CD83	448	591	660	1.32	1.47
CD85	453	476	673	1.05	1.49
CE11	233	257	335	1.10	1.43
CE21	336	502	561	1.49	1.67
CE31	354	467	548	1.32	1.55
CE41	391	469	558	1.20	1.43
CE51	428	579	647	1.35	1.51
CE61	470	551	688	1.17	1.46
CE71	429	473	582	1.10	1.36

Appendix B-VI.1d (Continued)

Grid	SN6	SN5	SN4	SN5/SN6	SN4/SN6
DB15	420	618	615	1.47	1.47
DB17	459	585	539	1.27	1.17
DB19	457	508	551	1.11	1.20
DB25	411	460	448	1.12	1.09
DB27	401	540	572	1.35	1.43
DB29	425	573	634	1.35	1.49
DC11	354	223	273	0.63	0.77
DC13	414	343	450	0.83	1.08
DC21	415	369	431	0.89	1.04
DC23	419	432	551	1.03	1.31
DC31	426	414	464	0.97	1.09
DC33	434	539	557	1.24	1.29
DC71	370	333	383	0.90	1.03
DC73	308	190	234	0.62	0.76
DC75	322	224	266	0.70	0.83

Appendix B-VI.2a: Fallow-canola yields (g/m^2) by weather grid points for historical (1x; SN6) and doubled (2x; SN5 and SN4) atmospheric CO_2 concentrations.

Grid	SN6	SN5	SN4	SN5/SN6	SN4/SN6
BC49	135	229	259	1.69	1.92
BC59	102	218	201	2.14	1.97
BC69	87	195	212	2.23	2.43
BC79	75	205	146	2.74	1.95
BC89	125	312	271	2.51	2.18
BC99	124	327	312	2.62	2.51
BD31	111	273	303	2.45	2.72
BD33	196	330	353	1.69	1.8
BD35	155	253	291	1.63	1.88
BD37	168	201	285	1.19	1.69
BD39	156	196	272	1.25	1.74
BD41	178	305	332	1.71	1.86
BD43	175	232	265	1.33	1.52
BD45	187	234	277	1.25	1.49
BD47	179	205	276	1.14	1.54
BD49	174	189	265	1.09	1.53
BD51	139	301	306	2.16	2.2
BD53	145	194	190	1.34	1.31
BD55	191	212	269	1.11	1.41
BD57	168	169	224	1.01	1.34
BD59	163	176	233	1.08	1.43
BD61	183	319	302	1.74	1.65
BD63	187	224	293	1.2	1.56
BD65	181	198	296	1.09	1.63
BD67	177	197	254	1.12	1.43
BD69	144	162	222	1.13	1.54
BD71	220	322	365	1.46	1.66
BD73	209	245	301	1.17	1.44
BD75	183	197	298	1.07	1.63
BD77	93	93	128	1	1.38
BD79	141	168	238	1.2	1.69
BD81	244	332	361	1.36	1.48
BD83	223	256	304	1.15	1.37
BD85	219	242	307	1.1	1.4
BD87	164	179	253	1.09	1.54
BD89	150	155	252	1.04	1.68
BD91	265	326	348	1.23	1.32
BD93	251	268	312	1.07	1.25
BD95	246	270	314	1.1	1.28
BD97	216	219	276	1.02	1.28
BD99	174	168	251	0.96	1.44
BE31	154	199	282	1.29	1.83
BE41	185	281	319	1.52	1.72
BE51	173	196	275	1.13	1.59
BE61	121	140	259	1.16	2.15
BE71	126	140	210	1.11	1.66
BE81	158	172	241	1.09	1.53
BE91	170	181	245	1.06	1.44
CB77	143	353	351	2.47	2.46
CB79	178	274	282	1.54	1.59
CB87	203	306	313	1.51	1.54
CB89	222	303	304	1.36	1.37
CB97	200	329	337	1.64	1.68
CB99	236	285	306	1.21	1.3
CC17	83	226	200	2.71	2.39
CC19	152	346	347	2.27	2.28
CC25	64	190	148	2.95	2.3
CC27	130	322	314	2.48	2.42
CC29	238	371	378	1.56	1.59

Appendix B-VI.2a (Continued)

Grid	SN6	SN5	SN4	SN5/SN6	SN4/SN6
CC35	144	342	291	2.38	2.03
CC37	182	292	293	1.6	1.61
CC39	280	365	359	1.31	1.28
CC43	158	349	307	2.21	1.95
CC45	211	369	348	1.75	1.65
CC47	247	372	361	1.51	1.46
CC49	288	333	339	1.16	1.18
CC53	139	353	326	2.55	2.35
CC55	201	369	369	1.83	1.83
CC57	253	371	372	1.47	1.47
CC59	301	351	358	1.16	1.19
CC65	171	308	306	1.8	1.79
CC67	250	369	372	1.48	1.49
CC69	248	260	279	1.05	1.13
CC77	165	378	373	2.3	2.26
CC79	237	373	371	1.57	1.56
CC87	156	362	361	2.33	2.32
CC89	222	370	373	1.67	1.69
CC97	246	338	352	1.37	1.43
CD11	282	335	363	1.19	1.29
CD13	264	303	329	1.14	1.25
CD15	254	260	314	1.02	1.24
CD17	250	243	292	0.97	1.17
CD19	236	237	305	1	1.29
CD21	288	328	356	1.14	1.24
CD23	282	315	349	1.12	1.24
CD25	265	267	321	1.01	1.21
CD27	279	303	322	1.09	1.15
CD29	227	188	209	0.83	0.92
CD31	301	325	341	1.08	1.14
CD33	278	269	311	0.97	1.12
CD35	267	264	301	0.99	1.13
CD37	283	282	312	1	1.1
CD39	270	285	327	1.06	1.21
CD41	315	335	357	1.06	1.13
CD43	298	282	304	0.94	1.02
CD45	276	263	296	0.95	1.07
CD47	269	270	291	1	1.08
CD49	281	296	322	1.05	1.15
CD51	299	303	318	1.01	1.06
CD53	299	284	314	0.95	1.05
CD55	288	296	321	1.03	1.12
CD57	190	188	216	0.99	1.14
CD59	280	298	330	1.06	1.18
CD61	295	335	364	1.13	1.23
CD63	300	328	347	1.09	1.15
CD67	281	303	324	1.08	1.15
CD69	201	162	195	0.8	0.97
CD71	272	336	353	1.23	1.3
CD73	247	221	265	0.89	1.07
CD77	278	289	313	1.04	1.12
CD79	286	303	322	1.06	1.12
CD81	271	337	351	1.24	1.3
CD83	269	298	323	1.11	1.2
CD85	270	291	311	1.08	1.15
CE11	207	177	210	0.86	1.02
CE21	251	244	308	0.97	1.23
CE31	249	284	304	1.14	1.22
CE41	271	280	309	1.03	1.14
CE51	273	274	302	1	1.11
CE61	286	290	313	1.01	1.09
CE71	278	260	288	0.93	1.03

Appendix B-VI.2a (Continued)

Grid	SN6	SN5	SN4	SN5/SN6	SN4/SN6
DB15	208	345	347	1.66	1.67
DB17	237	339	348	1.43	1.47
DB19	251	308	321	1.23	1.28
DB25	203	322	328	1.59	1.62
DB27	215	339	347	1.57	1.61
DB29	229	327	336	1.43	1.47
DC11	223	262	267	1.17	1.2
DC13	244	292	315	1.2	1.29
DC21	232	289	291	1.25	1.26
DC23	236	306	317	1.3	1.35
DC31	232	294	298	1.27	1.28
DC33	248	333	333	1.34	1.35
DC71	185	286	295	1.54	1.59
DC73	163	191	200	1.17	1.23
DC75	208	242	250	1.16	1.2

Appendix B-VI.2b: Fallow-spring wheat rotation yields (g/m^2) by weather grid points for historical (1x; SN6) and doubled (2x; SN5 and SN4) atmospheric CO_2 concentrations.

Grid	SN6	SN5	SN4	SN5/SN6	SN4/SN6
BC49	158	200	204	1.26	1.29
BC59	134	206	198	1.55	1.48
BC69	123	207	193	1.68	1.57
BC79	112	206	166	1.84	1.48
BC89	180	265	242	1.47	1.34
BC99	171	233	217	1.36	1.27
BD31	134	222	210	1.66	1.57
BD33	198	284	267	1.44	1.35
BD35	167	240	242	1.43	1.45
BD37	179	221	279	1.24	1.56
BD39	182	231	280	1.27	1.54
BD41	199	264	256	1.33	1.29
BD43	169	227	232	1.34	1.38
BD45	174	227	248	1.3	1.43
BD47	178	222	267	1.25	1.5
BD49	179	223	272	1.25	1.52
BD51	183	260	260	1.42	1.42
BD53	148	206	208	1.39	1.41
BD55	179	218	269	1.22	1.5
BD57	144	162	191	1.12	1.32
BD59	178	219	270	1.23	1.52
BD61	210	290	294	1.38	1.41
BD63	185	225	240	1.22	1.3
BD65	186	230	270	1.24	1.45
BD67	162	203	227	1.25	1.4
BD69	163	194	249	1.19	1.53
BD71	244	322	347	1.32	1.42
BD73	186	227	247	1.22	1.33
BD75	164	208	266	1.27	1.62
BD77	105	125	139	1.19	1.33
BD79	143	174	221	1.22	1.55
BD81	247	311	334	1.26	1.35
BD83	193	240	248	1.24	1.28
BD85	224	279	295	1.25	1.32
BD87	164	190	226	1.16	1.38
BD89	150	167	228	1.11	1.51
BD91	226	282	272	1.25	1.2
BD93	243	298	317	1.22	1.3
BD95	228	284	288	1.24	1.26
BD97	190	216	237	1.14	1.25
BD99	164	180	219	1.09	1.33
BE31	162	221	283	1.37	1.74
BE41	185	246	264	1.33	1.43
BE51	174	225	274	1.3	1.58
BE61	131	162	254	1.23	1.93
BE71	136	160	213	1.17	1.56
BE81	161	187	233	1.16	1.45
BE91	163	188	221	1.15	1.35
CB77	161	205	191	1.28	1.19
CB79	162	190	175	1.17	1.08
CB87	200	248	233	1.24	1.17
CB89	206	253	233	1.23	1.13
CB97	223	287	270	1.28	1.21
CB99	216	264	245	1.22	1.14
CC17	117	192	177	1.64	1.51
CC19	172	224	216	1.31	1.26
CC25	100	173	144	1.74	1.44
CC27	151	198	181	1.31	1.2
CC29	184	230	221	1.25	1.2

Appendix B-VI.2b (Continued).

Grid	SN6	SN5	SN4	SN5/SN6	SN4/SN6
CC35	158	208	194	1.31	1.23
CC37	166	206	192	1.24	1.16
CC39	191	233	215	1.22	1.13
CC43	165	213	191	1.29	1.16
CC45	176	218	200	1.24	1.14
CC47	182	222	205	1.22	1.13
CC49	192	225	215	1.17	1.12
CC53	161	210	192	1.3	1.19
CC55	172	216	201	1.26	1.17
CC57	181	221	207	1.22	1.14
CC59	187	220	206	1.17	1.1
CC65	158	195	177	1.24	1.12
CC67	180	219	202	1.22	1.12
CC69	183	205	194	1.12	1.06
CC77	165	212	195	1.29	1.18
CC79	179	223	208	1.24	1.16
CC87	151	191	177	1.26	1.17
CC89	172	215	198	1.25	1.15
CC97	169	199	189	1.18	1.12
CD11	229	284	278	1.24	1.22
CD13	228	286	292	1.25	1.28
CD15	206	242	239	1.18	1.16
CD17	205	239	240	1.16	1.17
CD19	203	233	256	1.15	1.26
CD21	226	279	271	1.23	1.19
CD23	236	291	291	1.24	1.23
CD25	245	292	307	1.19	1.26
CD27	259	322	326	1.24	1.26
CD29	187	196	204	1.04	1.09
CD31	209	250	245	1.19	1.17
CD33	276	322	321	1.17	1.16
CD35	233	270	273	1.16	1.17
CD37	224	277	272	1.24	1.22
CD39	238	303	310	1.27	1.3
CD41	229	270	268	1.18	1.17
CD43	245	280	273	1.15	1.12
CD45	265	302	307	1.14	1.16
CD47	238	277	279	1.17	1.17
CD49	235	296	294	1.26	1.25
CD51	209	243	231	1.16	1.1
CD53	261	309	314	1.18	1.2
CD55	287	350	351	1.22	1.23
CD57	212	244	251	1.15	1.18
CD59	221	274	272	1.24	1.24
CD61	216	264	258	1.22	1.19
CD63	196	240	230	1.22	1.17
CD67	192	233	229	1.21	1.19
CD69	176	172	180	0.98	1.02
CD71	178	210	202	1.18	1.13
CD73	171	187	184	1.09	1.07
CD77	177	205	199	1.15	1.12
CD79	181	214	209	1.18	1.15
CD81	174	206	198	1.19	1 14
CD83	177	204	199	1.16	1 13
CD85	176	205	198	1.16	1.12
CE11	183	197	200	1.08	1.1
CE21	191	220	233	1.15	1.22
CE31	236	299	305	1.27	1.29
CE41	256	316	315	1.23	1.23
CE51	206	249	252	1.2	1.22

Appendix B-VI.2b (Continued).

Grid	SN6	SN5	SN4	SN5/SN6	SN4/SN6
CE61	200	242	243	1.21	1.22
CE71	183	204	203	1.11	1.11
DB15	174	215	205	1.23	1.18
DB17	180	218	208	1.21	1.16
DB19	218	267	253	1.23	1.16
DB25	193	243	238	1.26	1.23
DB27	192	241	243	1.25	1.27
DB29	209	265	260	1.27	1.24
DC11	178	207	196	1.16	1.1
DC13	198	240	236	1.21	1.19
DC21	201	243	240	1.21	1.19
DC23	241	301	295	1.25	1.22
DC31	220	272	264	1.23	1.2
DC33	251	315	313	1.26	1.25
DC71	173	212	205	1.23	1.19
DC73	163	187	176	1.15	1.08
DC75	161	187	183	1.16	1.14

Appendix B-VI.2c: Fallow-winter wheat rotation yields (g/m^2) by weather grid points for historical (1x; SN6) and doubled (2x; SN5 and SN4) atmospheric CO_2 concentrations.

Grid	SN6	SN5	SN4	SN5/SN6	SN4/SN6
BC49	187	214	214	1.15	1.15
BC59	171	220	219	1.28	1.28
BC69	175	305	210	1.74	1.2
BC79	146	201	198	1.38	1.35
BC89	240	231	227	0.96	0.95
BC99	283	322	331	1.14	1.17
BD31	187	237	223	1.27	1.2
BD33	205	264	241	1.29	1.17
BD35	204	229	228	1.12	1.12
BD37	198	212	249	1.07	1.26
BD39	172	221	242	1.28	1.41
BD41	203	240	253	1.18	1.24
BD43	178	223	235	1.26	1.32
BD45	277	212	228	0.77	0.82
BD47	258	219	224	0.85	0.87
BD49	171	216	249	1.26	1.45
BD51	215	244	278	1.13	1.29
BD53	178	211	220	1.18	1.24
BD55	281	215	237	0.76	0.84
BD57	222	262	184	1.18	0.83
BD59	168	211	242	1.25	1.44
BD61	227	250	251	1.1	1.1
BD63	262	209	215	0.8	0.82
BD65	169	214	228	1.27	1.35
BD67	146	284	289	1.94	1.97
BD69	143	180	224	1.27	1.57
BD71	225	339	315	1.51	1.4
BD73	180	208	217	1.15	1.2
BD75	166	192	222	1.16	1.33
BD77	115	126	152	1.09	1.32
BD79	139	169	272	1.22	1.96
BD81	327	269	264	0.82	0.81
BD83	188	223	215	1.18	1.14
BD85	213	253	256	1.19	1.2
BD87	147	223	242	1.52	1.65
BD89	157	160	301	1.02	1.92
BD91	236	237	233	1	0.99
BD93	223	274	279	1.23	1.25
BD95	222	242	253	1.09	1.14
BD97	181	199	259	1.1	1.43
BD99	163	172	288	1.06	1.77
BE31	166	210	238	1.27	1.44
BE41	211	220	225	1.04	1.07
BE51	171	222	249	1.3	1.45
BE61	132	145	248	1.1	1.89
BE71	138	156	224	1.12	1.62
BE81	165	201	246	1.22	1.49
BE91	171	216	259	1.26	1.51
CB77	186	345	266	1.86	1.43
CB79	183	232	284	1.27	1.55
CB87	218	299	268	1.37	1.23
CB89	223	268	254	1.2	1.14
CB97	239	272	259	1.14	1.08
CB99	219	277	248	1.26	1.13
CC17	138	349	309	2.54	2.24
CC19	220	298	301	1.35	1.37
CC25	128	361	370	2.83	2.9
CC27	162	290	345	1.79	2.14
CC29	188	271	283	1.44	1.51

Appendix B-VI.2c (Continued).

Grid	SN6	SN5	SN4	SN5/SN6	SN4/SN6
CC35	256	504	387	1.96	1.51
CC37	192	327	345	1.7	1.79
CC39	201	196	302	0.97	1.5
CC43	190	277	173	1.46	0.91
CC45	200	350	320	1.75	1.6
CC47	209	360	458	1.72	2.19
CC49	201	256	230	1.28	1.15
CC53	275	376	365	1.37	1.32
CC55	206	342	249	1.66	1.21
CC57	209	515	278	2.46	1.33
CC59	213	345	350	1.62	1.64
CC65	193	277	335	1.44	1.74
CC67	209	378	243	1.8	1.16
CC69	203	216	266	1.06	1.31
CC77	236	271	448	1.15	1.9
CC79	209	369	421	1.76	2.01
CC87	247	277	249	1.12	1.01
CC89	203	370	378	1.82	1.86
CC97	198	445	254	2.25	1.29
CD11	238	273	250	1.15	1.05
CD13	238	232	233	0.97	0.98
CD15	212	213	210	1.01	0.99
CD17	210	218	215	1.04	1.02
CD19	205	334	227	1.63	1.11
CD21	243	255	258	1.05	1.07
CD23	253	303	274	1.2	1.09
CD25	256	254	261	0.99	1.02
CD27	269	276	282	1.03	1.05
CD29	191	200	199	1.05	1.05
CD31	224	265	297	1.18	1.32
CD33	288	283	306	0.98	1.06
CD35	247	239	241	0.97	0.98
CD37	241	242	286	1.01	1.19
CD39	252	266	289	1.05	1.15
CD41	246	263	267	1.07	1.08
CD43	255	280	271	1.1	1.06
CD45	277	275	286	0.99	1.03
CD47	257	309	261	1.2	1.02
CD49	247	296	307	1.2	1.24
CD51	222	211	226	0.95	1.02
CD53	270	302	306	1.12	1.13
CD55	293	331	343	1.13	1.17
CD57	246	248	262	1.01	1.07
CD59	246	317	301	1.29	1.22
CD61	239	451	291	1.89	1.22
CD63	210	357	356	1.7	1.7
CD67	215	411	347	1.91	1.61
CD69	188	227	266	1.21	1.42
CD71	202	378	282	1.87	1.4
CD73	171	217	215	1.27	1.25
CD77	200	332	381	1.66	1.9
CD79	201	390	447	1.94	2.22
CD81	207	381	365	1.84	1.76
CD83	195	369	323	1.89	1.66
CD85	199	329	172	1.66	0.87
CE11	188	198	198	1.05	1.05
CE21	204	234	206	1.14	1.01
CE31	251	358	277	1.43	1.1
CE41	271	277	280	1.02	1.03
CE51	223	349	396	1.57	1.78

Appendix B-VI.2c (Continued).

Grid	SN6	SN5	SN4	SN5/SN6	SN4/SN6
CE61	219	310	311	1.42	1.42
CE71	199	211	387	1.06	1.94
DB15	202	416	254	2.06	1.26
DB17	200	277	308	1.39	1.54
DB19	229	318	307	1.39	1.34
DB25	215	367	229	1.71	1.07
DB27	219	255	246	1.16	1.12
DB29	235	308	252	1.31	1.08
DC11	191	251	271	1.31	1.42
DC13	219	265	297	1.21	1.36
DC21	216	300	260	1.39	1.21
DC23	243	258	293	1.06	1.2
DC31	230	245	248	1.07	1.08
DC33	260	288	301	1.11	1.16
DC71	189	214	212	1.13	1.12
DC73	151	187	215	1.23	1.42
DC75	161	176	178	1.09	1.11

Appendix B-VI.2d: Fallow-corn rotation yields (g/m^2) by weather grid points for historical (1x; SN6) and doubled (2x; SN5 and SN4) atmospheric CO_2 concentrations. 0 represents grid boxes without sufficient heat for corn to growth under current climate.

Grid	SN6	SN5	SN4	SN5/SN6	SN4/SN6
BC49	0	389	465	0	0
BC89	0	656	715	0	0
BC99	0	711	772	0	0
BD31	0	399	424	0	0
BD33	0	590	648	0	0
BD35	0	453	533	0	0
BD37	323	395	633	1.22	1.95
BD39	317	364	585	1.15	1.84
BD41	0	519	618	0	0
BD43	0	448	565	0	0
BD45	386	443	579	1.15	1.5
BD47	357	384	627	1.08	1.76
BD49	319	370	577	1.16	1.81
BD51	0	526	586	0	0
BD53	0	349	430	0	0
BD55	376	395	639	1.05	1.7
BD57	294	316	443	1.07	1.51
BD59	285	339	558	1.19	1.96
BD61	0	546	598	0	0
BD63	0	431	531	0	0
BD65	382	379	584	0.99	1.53
BD67	325	353	512	1.09	1.58
BD69	281	327	553	1.16	1.96
BD71	0	599	710	0	0
BD73	0	454	576	0	0
BD75	385	374	672	0.97	1.74
BD77	204	192	235	0.94	1.15
BD79	257	282	480	1.1	1.86
BD81	0	627	743	0	0
BD83	0	491	608	0	0
BD85	437	451	614	1.03	1.41
BD87	0	302	501	0	0
BD89	0	275	503	0	0
BD91	0	691	762	0	0
BD93	0	565	672	0	0
BD95	0	529	643	0	0
BD97	0	404	573	0	0
BD99	0	322	493	0	0
BE31	268	353	545	1.32	2.03
BE41	0	585	663	0	0
BE51	318	380	585	1.19	1.84
BE61	196	235	555	1.2	2.82
BE71	219	236	429	1.08	1.96
BE81	308	301	481	0.98	1.56
BE91	0	329	475	0	0
CB77	0	754	758	0	0
CB79	0	614	659	0	0
CB87	0	642	668	0	0
CB89	0	647	679	0	0
CB97	0	666	699	0	0
CB99	0	623	665	0	0
CC19	0	759	817	0	0
CC27	0	743	786	0	0
CC29	0	838	875	0	0
CC37	0	713	760	0	0
CC39	0	837	865	0	0
CC45	0	832	840	0	0
CC47	0	841	853	0	0

Appendix B-VI.2d (Continued).

Grid	SN6	SN5	SN4	SN5/SN6	SN4/SN6
CC49	0	741	796	0	0
CC55	0	829	838	0	0
CC57	0	841	859	0	0
CC59	0	790	815	0	0
CC65	0	706	753	0	0
CC67	0	852	862	0	0
CC69	0	612	709	0	0
CC77	0	856	851	0	0
CC79	0	849	864	0	0
CC87	0	795	806	0	0
CC89	0	845	855	0	0
CC97	0	723	780	0	0
CD11	0	742	808	0	0
CD13	0	633	743	0	0
CD15	0	561	663	0	0
CD17	0	502	610	0	0
CD19	0	479	649	0	0
CD21	0	745	814	0	0
CD23	0	682	782	0	0
CD25	0	606	719	0	0
CD27	0	642	727	0	0
CD29	0	396	482	0	0
CD31	0	756	819	0	0
CD33	0	673	759	0	0
CD35	0	591	684	0	0
CD37	0	611	727	0	0
CD39	0	607	709	0	0
CD41	0	761	821	0	0
CD43	0	639	753	0	0
CD45	0	609	728	0	0
CD47	0	608	690	0	0
CD49	0	633	720	0	0
CD51	0	668	765	0	0
CD53	0	675	781	0	0
CD55	0	687	784	0	0
CD57	0	441	571	0	0
CD59	0	666	749	0	0
CD61	0	772	831	0	0
CD63	0	748	830	0	0
CD67	0	683	773	0	0

Appendix B-VI.3a: Irrigated canola yields (g/m^2) by weather grid points for historical (1x; SN6) and doubled (2x; SN5 and SN4) atmospheric CO_2 concentrations.

Grid	SN6	SN5	SN4	SN5/SN6	SN4/SN6
BC49	205	374	377	1.82	1.83
BC59	129	325	313	2.52	2.42
BC69	105	261	264	2.48	2.51
BC79	94	262	262	2.77	2.77
BC89	153	354	353	2.31	2.31
BC99	138	362	380	2.63	2.76
BD31	176	399	405	2.26	2.29
BD33	282	394	403	1.40	1.43
BD35	279	365	377	1.31	1.35
BD37	299	342	350	1.14	1.17
BD39	299	342	347	1.15	1.16
BD41	263	414	411	1.57	1.56
BD43	294	324	354	1.10	1.20
BD45	308	341	345	1.11	1.12
BD47	301	324	338	1.08	1.12
BD49	297	333	334	1.12	1.13
BD51	212	406	406	1.91	1.91
BD53	292	345	359	1.18	1.23
BD55	309	330	338	1.07	1.09
BD57	305	331	333	1.08	1.09
BD59	294	323	327	1.10	1.11
BD61	246	406	411	1.65	1.67
BD63	282	347	356	1.23	1.26
BD65	301	339	355	1.13	1.18
BD67	301	340	347	1.13	1.15
BD69	288	324	329	1.13	1.14
BD71	277	406	404	1.47	1.46
BD73	308	355	365	1.15	1.19
BD75	309	345	358	1.12	1.16
BD77	269	305	313	1.13	1.16
BD79	295	332	336	1.12	1.14
BD81	305	406	412	1.33	1.35
BD83	296	344	344	1.16	1.16
BD85	307	337	353	1.10	1.15
BD87	300	337	344	1.12	1.15
BD89	299	339	346	1.13	1.16
BD91	301	381	384	1.27	1.28
BD93	304	340	347	1.12	1.14
BD95	309	350	358	1.13	1.16
BD97	317	354	360	1.12	1.13
BD99	310	346	351	1.12	1.13
BE31	292	336	335	1.15	1.15
BE41	273	368	379	1.35	1.39
BE51	295	334	341	1.13	1.16
BE61	293	334	337	1.14	1.15
BE71	281	319	320	1.14	1.14
BE81	292	336	338	1.15	1.16
BE91	295	337	341	1.14	1.16
CB77	171	393	392	2.29	2.29
CB79	225	375	376	1.67	1.67
CB87	252	369	366	1.47	1.45
CB89	272	370	367	1.36	1.35
CB97	245	365	357	1.49	1.46
CB99	277	351	350	1.27	1.26
CC17	105	250	242	2.38	2.30
CC19	175	397	398	2.27	2.27
CC25	79	216	209	2.73	2.65
CC27	146	358	375	2.44	2.56
CC29	259	406	400	1.57	1.54

Appendix B-VI.3a (Continued)

Grid	SN6	SN5	SN4	SN5/SN6	SN4/SN6
CC35	162	372	381	2.30	2.35
CC37	250	378	382	1.51	1.53
CC39	292	399	398	1.37	1.36
CC43	174	362	361	2.07	2.07
CC45	223	396	381	1.78	1.71
CC47	257	394	390	1.53	1.52
CC49	306	388	390	1.27	1.27
CC53	162	379	361	2.33	2.22
CC55	221	395	374	1.79	1.69
CC57	264	412	377	1.56	1.43
CC59	320	404	406	1.26	1.27
CC65	212	377	379	1.78	1.79
CC67	262	402	384	1.53	1.46
CC69	306	376	382	1.23	1.25
CC77	195	407	366	2.08	1.87
CC79	246	401	398	1.63	1.61
CC87	186	398	398	2.14	2.13
CC89	236	391	380	1.65	1.61
CC97	282	385	383	1.37	1.36
CD11	313	384	388	1.23	1.24
CD13	313	368	378	1.17	1.20
CD15	310	349	360	1.12	1.16
CD17	310	350	360	1.13	1.16
CD19	310	360	369	1.16	1.19
CD21	313	388	392	1.24	1.25
CD23	316	374	383	1.18	1.21
CD25	311	356	367	1.15	1.18
CD27	320	355	369	1.11	1.15
CD29	311	346	353	1.11	1.13
CD31	323	391	393	1.21	1.22
CD33	320	369	378	1.15	1.18
CD35	317	353	364	1.11	1.15
CD37	318	362	365	1.14	1.15
CD39	317	359	363	1.13	1.14
CD41	340	390	395	1.15	1.16
CD43	333	374	385	1.12	1.16
CD45	323	355	371	1.10	1.15
CD47	305	347	356	1.14	1.17
CD49	315	355	364	1.13	1.16
CD51	334	390	397	1.17	1.19
CD53	335	368	379	1.10	1.13
CD55	320	366	374	1.15	1.17
CD57	298	336	346	1.13	1.16
CD59	316	367	372	1.16	1.18
CD61	315	394	397	1.25	1.26
CD63	323	387	397	1.20	1.23
CD67	297	371	383	1.25	1.29
CD69	295	336	347	1.14	1.18
CD71	291	389	388	1.34	1.34
CD73	305	357	366	1.17	1.20
CD77	295	371	378	1.26	1.28
CD79	286	375	383	1.31	1.34
CD81	287	388	392	1.35	1.37
CD83	298	373	379	1.25	1.27
CD85	289	373	374	1.29	1.29
CE11	291	329	335	1.13	1.15
CE21	301	346	355	1.15	1.18
CE31	299	342	348	1.14	1.16
CE41	304	338	347	1.11	1.14
CE51	299	349	352	1.17	1.18
CE61	301	363	368	1.20	1.22
CE71	288	360	363	1.25	1.26

Appendix B-VI.3a (Continued)

Grid	SN6	SN5	SN4	SN5/SN6	SN4/SN6
DB15	247	377	374	1.52	1.51
DB17	267	376	369	1.41	1.38
DB19	294	354	352	1.21	1.20
DB25	247	356	358	1.44	1.45
DB27	248	369	377	1.49	1.52
DB29	267	373	368	1.40	1.38
DC11	292	331	334	1.13	1.15
DC13	285	346	351	1.21	1.23
DC21	274	347	348	1.26	1.27
DC23	276	353	357	1.28	1.29
DC31	275	344	345	1.25	1.25
DC33	279	366	365	1.31	1.30
DC71	232	330	332	1.42	1.43
DC73	252	312	316	1.24	1.25
DC75	270	310	314	1.15	1.16

Appendix B-VI.3b: Irrigated spring wheat yields (g/m^2) by weather grid points for historical (1x; SN6) and doubled (2x; SN5 and SN4) atmospheric CO_2 concentrations.

Grid	SN6	SN5	SN4	SN5/SN6	SN4/SN6
BC49	347	420	406	1.21	1.17
BC59	286	415	403	1.45	1.41
BC69	236	398	386	1.69	1.64
BC79	213	401	388	1.88	1.82
BC89	331	425	413	1.28	1.25
BC99	334	418	406	1.25	1.22
BD31	360	430	402	1.20	1.12
BD33	388	448	419	1.16	1.08
BD35	379	442	421	1.17	1.11
BD37	385	437	435	1.13	1.13
BD39	373	431	436	1.15	1.17
BD41	380	442	422	1.16	1.11
BD43	381	427	416	1.12	1.09
BD45	383	416	416	1.09	1.09
BD47	378	415	420	1.10	1.11
BD49	355	405	411	1.14	1.16
BD51	362	439	419	1.21	1.16
BD53	380	428	415	1.13	1.09
BD55	385	419	423	1.09	1.10
BD57	369	391	395	1.06	1.07
BD59	350	386	393	1.10	1.12
BD61	376	442	420	1.17	1.12
BD63	377	426	421	1.13	1.11
BD65	381	416	430	1.09	1.13
BD67	370	413	416	1.12	1.12
BD69	348	401	410	1.15	1.18
BD71	397	466	440	1.17	1.11
BD73	381	427	417	1.12	1.09
BD75	382	436	430	1.14	1.12
BD77	335	367	375	1.09	1.12
BD79	358	406	412	1.13	1.15
BD81	398	462	430	1.16	1.08
BD83	371	415	404	1.12	1.09
BD85	381	425	431	1.11	1.13
BD87	367	414	418	1.13	1.14
BD89	363	418	415	1.15	1.14
BD91	386	443	420	1.15	1.09
BD93	379	425	426	1.12	1.12
BD95	385	436	442	1.13	1.15
BD97	381	431	422	1.13	1.11
BD99	371	419	408	1.13	1.10
BE31	347	418	427	1.21	1.23
BE41	375	444	430	1.18	1.14
BE51	355	408	417	1.15	1.17
BE61	354	409	417	1.15	1.18
BE71	339	384	385	1.13	1.13
BE81	353	413	416	1.17	1.18
BE91	363	407	412	1.12	1.13
CB77	337	418	406	1.24	1.20
CB79	362	412	398	1.14	1.10
CB87	368	426	408	1.16	1.11
CB89	372	424	409	1.14	1.10
CB97	369	441	418	1.19	1.13
CB99	369	423	415	1.15	1.12
CC17	234	401	385	1.71	1.64
CC19	361	424	413	1.17	1.14
CC25	188	378	361	2.01	1.92
CC27	333	415	403	1.25	1.21
CC29	379	427	415	1.13	1.09

Appendix B-VI.3b (Continued)

Grid	SN6	SN5	SN4	SN5/SN6	SN4/SN6
CC35	335	422	413	1.26	1.23
CC37	368	414	405	1.13	1.10
CC39	375	420	409	1.12	1.09
CC43	338	414	403	1.23	1.19
CC45	358	413	401	1.16	1.12
CC47	365	417	404	1.14	1.11
CC49	376	419	405	1.11	1.08
CC53	334	416	405	1.24	1.21
CC55	352	415	403	1.18	1.15
CC57	371	419	407	1.13	1.10
CC59	384	421	408	1.10	1.06
CC65	345	407	396	1.18	1.15
CC67	371	418	405	1.13	1.09
CC69	374	418	405	1.12	1.08
CC77	336	419	408	1.25	1.21
CC79	364	419	410	1.15	1.13
CC87	330	415	406	1.26	1.23
CC89	361	416	405	1.15	1.12
CC97	368	408	400	1.11	1.09
CD11	389	448	427	1.15	1.10
CD13	392	458	425	1.17	1.08
CD15	383	432	422	1.13	1.10
CD17	382	433	423	1.13	1.11
CD19	384	442	428	1.15	1.11
CD21	387	441	426	1.14	1.10
CD23	391	452	426	1.15	1.09
CD25	391	445	445	1.14	1.14
CD27	395	444	450	1.12	1.14
CD29	381	423	419	1.11	1.10
CD31	385	431	413	1.12	1.07
CD33	398	448	444	1.12	1.12
CD35	390	436	428	1.12	1.10
CD37	388	442	435	1.14	1.12
CD39	393	444	446	1.13	1.14
CD41	394	440	422	1.12	1.07
CD43	392	437	423	1.11	1.08
CD45	396	435	435	1.10	1.10
CD47	379	424	425	1.12	1.12
CD49	388	435	432	1.12	1.11
CD51	386	430	408	1.12	1.06
CD53	400	445	444	1.11	1.11
CD55	405	450	447	1.11	1.11
CD57	368	402	411	1.09	1.12
CD59	385	436	430	1.13	1.12
CD61	385	432	416	1.12	1.08
CD63	384	420	403	1.09	1.05
CD67	378	419	403	1.11	1.07
CD69	367	414	408	1.13	1.11
CD71	374	416	402	1.11	1.08
CD73	373	414	400	1.11	1.07
CD77	375	413	399	1.10	1.06
CD79	370	411	401	1.11	1.08
CD81	376	411	401	1.09	1.07
CD83	373	411	398	1.10	1.07
CD85	370	405	398	1.09	1.07
CE11	356	400	405	1.12	1.14
CE21	378	424	416	1.12	1.10
CE31	372	424	429	1.14	1.16
CE41	376	419	428	1.11	1.14
CE51	376	423	414	1.13	1.10
CE61	378	422	414	1.12	1.09
CE71	368	412	402	1.12	1.09

Appendix B-VI.3d (Continued)

Grid	SN6	SN5	SN4	SN5/SN6	SN4/SN6
DB15	361	409	400	1.13	1.11
DB17	368	408	398	1.11	1.08
DB19	375	419	414	1.12	1.10
DB25	366	413	402	1.13	1.10
DB27	365	408	401	1.12	1.10
DB29	375	424	414	1.13	1.11
DC11	355	407	399	1.14	1.12
DC13	372	423	411	1.14	1.11
DC21	367	427	408	1.16	1.11
DC23	372	436	436	1.17	1.17
DC31	370	435	428	1.18	1.16
DC33	378	448	447	1.18	1.18
DC71	338	396	392	1.17	1.16
DC73	332	376	380	1.13	1.14
DC75	336	371	374	1.11	1.11

Appendix B-VI.3c: Irrigated corn yields (g/m^2) by weather grid points for historical (1x; SN6) and doubled (2x; SN5 and SN4) atmospheric CO_2 concentrations. 0 represents grid boxes without sufficient heat for corn to growth under current climate.

Grid	SN6	SN5	SN4	SN5/SN6	SN4/SN6
BC49	0	764	778	0	0
BC89	0	755	776	0	0
BC99	0	782	799	0	0
BD31	0	817	821	0	0
BD33	0	811	816	0	0
BD35	0	759	772	0	0
BD37	666	727	740	1.09	1.11
BD39	667	699	711	1.05	1.07
BD41	0	834	843	0	0
BD43	0	750	750	0	0
BD45	699	723	725	1.03	1.04
BD47	676	685	713	1.01	1.05
BD49	669	671	686	1	1.02
BD51	0	836	841	0	0
BD53	0	734	741	0	0
BD55	691	703	727	1.02	1.05
BD57	682	697	691	1.02	1.01
BD59	647	645	656	1	1.01
BD61	0	829	835	0	0
BD63	0	719	734	0	0
BD65	694	715	729	1.03	1.05
BD67	690	716	731	1.04	1.06
BD69	651	664	674	1.02	1.04
BD71	0	814	828	0	0
BD73	0	749	764	0	0
BD75	697	715	758	1.03	1.09
BD77	635	642	654	1.01	1.03
BD79	672	684	695	1.02	1.03
BD81	0	828	839	0	0
BD83	0	731	743	0	0
BD85	679	717	728	1.05	1.07
BD87	0	693	707	0	0
BD89	0	706	716	0	0
BD91	0	780	793	0	0
BD93	0	730	744	0	0
BD95	0	730	741	0	0
BD97	0	747	758	0	0
BD99	0	730	744	0	0
BE31	654	668	675	1.02	1.03
BE41	0	746	756	0	0
BE51	670	665	673	0.99	1
BE61	655	658	675	1	1.03
BE71	647	629	649	0.97	1
BE81	660	676	699	1.02	1.06
BE91	0	707	716	0	0
CB77	0	799	797	0	0
CB79	0	779	787	0	0
CB87	0	766	769	0	0
CB89	0	757	756	0	0
CB97	0	746	741	0	0
CB99	0	739	732	0	0
CC19	0	834	853	0	0
CC27	0	804	827	0	0
CC29	0	867	889	0	0
CC37	0	808	824	0	0
CC39	0	826	855	0	0
CC45	0	805	824	0	0
CC47	0	804	833	0	0

Appendix B-VI.3c (Continued)

Grid	SN6	SN5	SN4	SN5/SN6	SN4/SN6
CC49	0	822	841	0	0
CC55	0	836	847	0	0
CC57	0	855	873	0	0
CC59	0	841	860	0	0
CC65	0	775	784	0	0
CC67	0	858	869	0	0
CC69	0	804	816	0	0
CC77	0	858	864	0	0
CC79	0	860	884	0	0
CC87	0	829	843	0	0
CC89	0	850	870	0	0
CC97	0	797	825	0	0
CD11	0	802	828	0	0
CD13	0	768	791	0	0
CD15	0	740	755	0	0
CD17	0	736	759	0	0
CD19	0	751	774	0	0
CD21	0	810	833	0	0
CD23	0	790	818	0	0
CD25	0	757	782	0	0
CD27	0	746	781	0	0
CD29	0	740	757	0	0
CD31	0	819	849	0	0
CD33	0	789	815	0	0
CD35	0	756	787	0	0
CD37	0	756	781	0	0
CD39	0	764	779	0	0
CD41	0	835	860	0	0
CD43	0	801	825	0	0
CD45	0	776	804	0	0
CD47	0	749	770	0	0
CD49	0	758	785	0	0
CD51	0	817	842	0	0
CD53	0	785	822	0	0
CD55	0	777	822	0	0
CD57	0	717	752	0	0
CD59	0	774	800	0	0
CD61	0	825	856	0	0
CD63	0	812	855	0	0
CD67	0	795	825	0	0

APPENDIX C

Model outputs averaged by Regional Municipalities of Alberta.

Appendix C-IV.1a: Average corn heat units (CHU), growing degree days with a base of 0°C (GDD_0) and growing degree days with a base of 5°C (GDD_5) averaged for the 15 crop reporting districts in Alberta for climate at the current atmospheric CO_2 level (1x) and for an atmospheric CO_2 concentration two times the current level (2x) .

	Regional Municipality	CHU		GDD_0		GDD_5	
		1x	2x	1x	2x	1x	2x
1	Improvement District 24	1700	2500	1682	2198	1099	1500
2	Improvement District 23	1686	2458	1558	2139	978	1463
3	Improvement District 22	1699	2497	1645	2157	961	1497
4	Improvement District 18	1713	2540	1695	2289	1094	1518
5	Improvement District 17	1672	2499	1654	2260	1021	1496
6	Improvement District 21	1692	2490	1585	2138	938	1500
7	Improvement District 20	1688	2450	1570	2170	970	1503
8	Fairview	1770	2566	1647	2247	1047	1577
9	Peace	1724	2524	1700	2300	1100	1529
10	Spirit River	1838	2630	1700	2300	1100	1638
11	Improvement District 19	1892	2692	1700	2300	1100	1692
12	Smoky River	1873	2684	1700	2300	1100	1684
13	Grande Prairie	1685	2481	1556	2156	956	1515
14	Improvement District 16	1555	2355	1529	2101	932	1392
15	Improvement District 15	1598	2447	1508	2123	921	1448
16	Athabasca	1807	2696	1700	2352	1100	1673
17	Barrhead	1774	2588	1694	2308	1100	1580
18	Westlock	1849	2662	1670	2316	1100	1659
19	Thorhild	1900	2700	1700	2330	1100	1700
20	Smoky Lake	1833	2700	1700	2331	1100	1700
21	St. Paul	1836	2700	1700	2321	1100	1700
22	Bonnyville	1815	2700	1700	2300	1100	1700
23	Two Hills	1900	2700	1700	2359	1100	1700
24	VermilionRiver	1935	2798	1825	2497	1137	1700
25	Minburn	1900	2700	1723	2500	1100	1700
26	Beaver	1902	2777	1794	2500	1150	1700
27	Lamont	1900	2700	1700	2496	1100	1700
28	Improvement District 13	1900	2700	1700	2500	1100	1700
29	Strathcona	1926	2888	1888	2500	1126	1700
30	Sturgeon	1961	2782	1782	2500	1165	1700
31	Lac Ste. Anne	1827	2633	1661	2298	1061	1627
32	Parkland	1817	2766	1767	2389	1100	1616
33	Improvement District 14	1379	2180	1409	1968	860	1290
34	Improvement District 12	1236	2036	1349	1908	775	1175
35	Improvement District 9	1168	1971	1223	1779	727	1172
36	Clearwater	1274	2076	1279	1860	775	1226
37	Brazeau	1700	2546	1590	2190	987	1500
38	Leduc	1887	2785	1787	2436	1100	1687
39	Wetaskiwin	1837	2645	1698	2372	1100	1640
40	Camrose	1997	2836	1836	2500	1125	1713
41	Ponoka	1803	2665	1686	2347	1087	1667
42	Flagstaff	2025	2882	1900	2500	1288	1775
43	Wainwright	1998	2809	1900	2500	1230	1752
44	Provost	2004	2804	1900	2500	1300	1794
45	Special Area 4	2006	2802	1870	2500	1270	1798
46	Special Area 3	2100	2896	1901	2597	1301	1896
47	Paintearth	2058	2856	1900	2500	1300	1708
48	Stettler	1992	2884	1885	2497	1281	1751
49	Lacombe	1833	2663	1683	2285	1089	1673
51	Mountain View	1623	2523	1605	2205	1016	1552
52	Kneehill	1991	2822	1850	2473	1260	1810
53	Starland	2100	2900	1900	2519	1300	1896
54	Special Area 2	2124	2881	1927	2587	1325	1872
55	Acadia Valley	2220	3015	2020	2700	1420	2015
56	Municipal District 7	2100	2900	1900	2660	1300	1900
57	Wheatland	2036	2842	1893	2568	1294	1852
58	Rocky View	1586	2475	1588	2191	1038	1568
59	Bighorn	1318	2139	1330	1930	893	1300
60	Improvement District 8	1290	2090	1290	1890	792	1287
61	Improvement District 5	1109	1967	1249	1833	714	1231
62	Foothill	1532	2346	1533	2124	953	1520
63	Vulcan	2145	2892	1957	2575	1309	1893
64	Newell	2224	2933	2024	2700	1400	1929
65	Cypress	2220	3005	2091	2709	1430	2004
66	CFB Suffield	2303	3100	2103	2707	1500	2100
67	Forty Mile	2292	3087	2103	2844	1496	2087
68	Warner	2224	3024	2032	2654	1431	1996
69	Taber	2300	3100	2100	2739	1500	2012
70	Lethbridge	2216	3008	2025	2662	1420	1900

Appendix C-IV.1a (Continued)

	Regional Municipality	CHU		GDD_0		GDD_5	
		1x	2x	1x	2x	1x	2x
71	Cardston	1996	2796	1891	2516	1291	1790
72	Willow Creek	1838	2637	1748	2378	1148	1697
73	Pincher Creek	1720	2520	1698	2310	1098	1534
74	Improvement District 4	1743	2543	1700	2317	1100	1560
75	Improvement District 6	1516	2318	1542	2116	942	1456
76	Cold Lake Air Weapons Range	1872	2700	1700	2300	1100	1700
77	CFB Wainwright	1918	2718	1900	2500	1290	1700

Appendix C-IV.1b: Average growing degree days with a base of 8°C (GDD_8), growing degree days with a base of 10°C (GDD_{10}) and heating degree days below 18°C (HDD_{18}) averaged for the 16 Regional Municipalitys in Alberta for climate at the current atmospheric CO_2 level (1x) and for an atmospheric CO_2 concentration two times the current level (2x) .

	Regional Municipality	GDD_8		GDD_{10}		HDD_{18}	
		1x	2x	1x	2x	1x	2x
1	Improvement District 24	799	1171	600	902	6734	5534
2	Improvement District 23	739	1122	593	900	6889	5689
3	Improvement District 22	731	1131	599	929	6593	5393
4	Improvement District 18	792	1218	604	970	6513	5255
5	Improvement District 17	742	1181	566	927	6300	5088
6	Improvement District 21	726	1136	600	918	6304	5103
7	Improvement District 20	736	1145	592	906	6211	4968
8	Fairview	784	1215	635	971	6136	4936
9	Peace	802	1209	612	1002	6200	5000
10	Spirit River	800	1246	650	984	5923	4630
11	Improvement District 19	827	1294	668	1026	6061	4840
12	Smoky River	802	1271	667	1001	6200	5000
13	Grande Prairie	728	1145	571	928	6008	4636
14	Improvement District 16	681	1083	526	861	5920	4644
15	Improvement District 15	705	1111	550	886	5943	4644
16	Athabasca	800	1294	647	1045	5992	4631
17	Barrhead	804	1235	634	1006	5812	4584
18	Westlock	805	1276	673	1034	5877	4629
19	Thorhild	811	1307	700	1100	5804	4590
20	Smoky Lake	835	1309	659	1069	6066	4600
21	St. Paul	864	1310	664	1081	6200	4605
22	Bonnyville	830	1300	649	1100	6200	4738
23	Two Hills	900	1329	700	1100	6154	4600
24	Vermilion River	900	1398	700	1118	6179	4600
25	Minburn	900	1400	700	1100	5909	4600
26	Beaver	900	1400	700	1125	5800	4570
27	Lamont	900	1398	700	1100	5800	4600
28	Improvement District 13	900	1400	700	1100	5800	4600
29	Strathcona	900	1400	700	1113	5800	4215
30	Sturgeon	900	1355	700	1127	5800	4228
31	Lac Ste. Anne	794	1252	663	996	5800	4523
32	Parkland	844	1327	657	1047	5800	4392
33	Improvement District 14	616	1008	487	797	5786	4581
34	Improvement District 12	569	932	447	732	5922	4571
35	Improvement District 9	549	931	434	731	5989	4676
36	Clearwater	569	944	444	733	5950	4552
37	Brazeau	740	1168	569	942	5800	4527
38	Leduc	868	1360	693	1086	5800	4203
39	Wetaskiwin	837	1306	670	1066	5800	4200
40	Camrose	906	1403	708	1111	5778	4202
41	Ponoka	834	1285	683	1045	5800	4200
42	Flagstaff	938	1435	763	1194	5793	4344
43	Wainwright	926	1426	733	1165	5858	4600
44	Provost	947	1447	800	1200	5800	4600
45	Special Area 4	953	1452	800	1226	5856	4489
46	Special Area 3	1047	1546	859	1323	5726	4201
47	Paintearth	905	1402	799	1200	5800	4274
48	Stettler	938	1419	747	1189	5704	4200
49	Lacombe	830	1287	686	1066	5783	4200
51	Mountain View	761	1219	627	978	5544	4194
52	Kneehill	964	1437	781	1176	5426	4200
53	Starland	1006	1496	810	1211	5419	4200
54	Special Area 2	1051	1532	877	1320	5615	4146
55	Acadia Valley	1144	1644	946	1422	5506	3960
56	Municipal District 7	1080	1580	880	1280	5400	4200
57	Wheatland	1025	1505	834	1232	5400	3972
58	Rocky View	763	1224	641	995	5432	4027
59	Bighorn	615	1019	500	816	5636	4206
60	Improvement District 8	595	993	493	793	5806	4476
61	Improvement District 5	539	945	426	733	5781	4417
62	Foothill	724	1193	598	932	5432	3928
63	Vulcan	1028	1527	833	1271	5172	3717
64	Newell	1114	1616	914	1368	5328	3809
65	Cypress	1135	1659	950	1428	5198	3629
66	CFB Suffield	1200	1700	1000	1500	5148	3757
67	Forty Mile	1173	1695	978	1419	4982	3411
68	Warner	1071	1611	874	1362	4918	3400
69	Taber	1145	1650	946	1400	5000	3400
70	Lethbridge	1058	1558	864	1335	5000	3400
71	Cardston	950	1438	786	1235	5000	3416
72	Willow Creek	871	1335	689	1105	5138	3634
73	Pincher Creek	811	1225	623	1024	5010	3793
74	Improvement District 4	826	1256	643	1052	5000	3800

Appendix C-IV.1b (Continued)

	Regional Municipality	GDD_8 1x	GDD_8 2x	GDD_{10} 1x	GDD_{10} 2x	HDD_{18} 1x	HDD_{18} 2x
75	Improvement District 6	724	1119	548	912	5340	3913
76	Cold Lake Air Weapons Range	800	1300	625	1027	6200	4670
77	CFB Wainwright	900	1400	777	1195	5800	4600

Appendix C-IV.1c: Frost free days (FFD) and winter wheat spring regrowth (RGRW) averaged for the 16 Regional Municipalitys in Alberta for climate at the current atmospheric CO_2 level (1x) and for an atmospheric CO_2 concentration two times the current level (2x) .

	Regional Municipality	FFD		RGRW	
		1x	2x	1x	2x
1	Improvement district 24	110	150	May 20	May 1
2	Improvement district 23	114	148	May 20	May 1
3	Improvement district 22	128	150	May 18	April 29
4	Improvement district 18	118	154	May 18	April 26
5	Improvement district 17	129	160	May 18	April 17
6	Improvement district 21	128	150	May 19	April 27
7	Improvement district 20	123	153	May 12	April 19
8	Fairview	130	159	May 15	April 19
9	Peace	130	153	May 20	April 27
10	Spirit River	130	169	May 10	April 12
11	Improvement district 19	130	169	May 15	April 17
12	Smoky River	130	170	May 19	April 23
13	Grande Prairie	125	165	May 10	April 9
14	Improvement district 16	126	163	May 10	April 9
15	Improvement district 15	127	150	May 19	April 2
16	Athabasca	130	170	May 10	March 29
17	Barrhead	122	158	May 10	March 26
18	Westlock	126	166	May 10	March 23
19	Thorhild	130	170	May 10	March 22
20	Smoky Lake	117	170	May 15	March 28
21	St. Paul	110	167	May 18	March 31
22	Bonnyville	119	170	May 20	March 31
23	Two Hills	116	168	May 16	March 28
24	Vermilion River	126	170	May 10	March 21
25	Minburn	130	170	May 10	March 21
26	Beaver	130	170	May 10	March 21
27	Lamont	130	170	May 10	March 21
28	Improvement district 13	130	170	May 10	March 21
29	Strathcona	130	170	May 10	March 21
30	Sturgeon	130	170	May 10	March 21
31	Lac Ste. Anne	128	163	May 12	March 24
32	Parkland	130	170	May 10	March 21
33	Improvement district 14	111	151	May 7	March 26
34	Improvement district 12	101	149	May 12	April 6
35	Improvement district 9	97	147	May 13	April 11
36	Clearwater	102	148	May 2	March 26
37	Brazeau	130	166	May 8	March 22
38	Leduc	130	170	May 10	March 21
39	Wetaskiwin	130	170	May 9	March 21
40	Camrose	130	170	May 10	March 21
41	Ponoka	130	170	May 7	March 20
42	Flagstaff	130	170	May 10	March 21
43	Wainwright	130	170	May 10	March 21
44	Provost	125	165	May 10	March 21
45	Special Area 4	126	166	May 10	March 27
46	Special Area 3	129	164	May 9	March 25
47	Paintearth	130	170	May 10	March 21
48	Stettler	130	170	May 9	March 21
49	Lacombe	128	170	May 6	March 20
51	Mountain View	121	162	April 26	March 17
52	Kneehill	130	170	April 28	March 12
53	Starland	130	170	April 30	March 19
54	Special Area 2	129	169	May 5	March 21
55	Acadia Valley	130	170	May 4	March 23
56	Municipal District 7	130	170	April 30	March 11
57	Wheatland	130	170	April 25	March 11
58	Rocky View	119	161	April 24	March 14
59	Bighorn	107	150	April 20	March 21
60	Improvement district 8	108	149	April 20	March 28
61	Improvement district 5	87	140	April 21	March 27
62	Foothill	111	155	April 30	March 17
63	Vulcan	130	170	April 13	March 2
64	Newell	131	170	April 24	March 10
65	Cypress	131	170	April 20	March 6
66	CFB Suffield	130	170	April 27	March 10
67	Forty Mile	147	170	April 9	March 1
68	Warner	139	170	March 31	February 28
69	Taber	140	173	April 3	February 28
70	Lethbridge	130	170	April 2	February 21
71	Cardston	130	170	April 1	February 27
72	Willow Creek	123	164	April 15	March 4
73	Pincher Creek	129	170	April 21	March 9
74	Improvement district 4	130	170	April 10	February 27
75	Improvement district 6	112	159	May 4	March 22

Appendix C-IV.1c (Conitnued)

	Regional Municipality	FFD		RGRW	
		1x	2x	1x	2x
76	Cold Lake Air Weapons Range	130	170	May 20	April 3
77	CFB Wainwright	123	163	May 10	March 21

Appendix C-V.1: Seeding dates averaged by Alberta Regional Municipalities for historical (1x; SN6) and doubled (2x; SN4 and SN5) atmospheric CO_2 concentrations.

	Regional Municipality	SN6	SN5	SN4	(SN5-SN6)	(SN4-SN6)
2	Improvement District 23	May 26	May 14	May 14	-12	-12
3	Improvement District 22	May 24	May 14	May 15	-10	-9
4	Improvement District 18	May 25	May 11	May 12	-14	-12
5	Improvement District 17	May 25	May 5	May 7	-20	-18
6	Improvement District 21	May 24	May 12	May 14	-12	-10
7	Improvement District 20	May 23	May 8	May 12	-15	-10
8	Fairview	May 22	May 10	May 12	-12	-10
9	Peace	May 24	May 10	May 10	-14	-14
10	Spirit River	May 19	May 8	May 12	-11	-7
11	Improvement District 19	May 20	May 8	May 11	-12	-10
12	Smoky River	May 23	May 9	May 9	-14	-14
13	County 1 Grande Prairie	May 20	May 3	May 8	-17	-12
14	Improvement District 16	May 20	Apr 30	May 4	-20	-16
15	Improvement District 15	May 26	Apr 28	May 4	-28	-22
16	County 12 Athabasca	May 22	Apr 27	May 2	-24	-19
17	County 11 Barrhead	May 23	Apr 25	May 1	-28	-22
18	Westlock	May 23	Apr 26	May 1	-27	-22
19	County 7 Thorhild	May 21	Apr 28	May 2	-23	-19
20	County 13 Smoky Lake	May 23	Apr 29	May 2	-25	-21
21	County 19 St. Paul	May 24	Apr 28	May 1	-26	-22
22	Bonnyville	May 24	Apr 27	May 1	-26	-22
23	County 21 Two Hills	May 24	Apr 28	May 1	-26	-22
24	County 24 Vermilion River	May 20	Apr 25	Apr 27	-25	-23
25	County 27 Minburn	May 22	Apr 27	Apr 29	-25	-22
26	County 9 Beaver	May 21	Apr 27	May 1	-24	-19
27	County 30 Lamont	May 21	Apr29	May 1	-22	-20
28	Improvement District 13	May 21	Apr 28	May 1	-23	-20
29	County 20 Strathcona	May 21	Apr 28	May 1	-23	-20
30	Sturgeon	May 20	Apr 26	Apr 29	-25	-21
31	County 28 Lac Ste. Anne	May 21	Apr 23	Apr 29	-28	-22
32	County 31 Parkland	May 20	Apr 24	Apr 28	-25	-22
33	Improvement District 14	May 20	Apr 26	Apr 28	-25	-22
34	Improvement District 12	May 25	May 2	May 6	-23	-19
35	Improvement District 9	May 23	May 1	May 2	-22	-21
36	Clearwater	May 17	Apr 22	Apr 23	-25	-24
37	Brazeau	May 20	Apr 22	Apr 24	-28	-26
38	County 25 Leduc	May 21	Apr 26	Apr 29	-25	-21
39	County 10 Wetaskiwin	May 21	Apr 24	Apr 27	-27	-24
40	County 22 Camrose	May 21	Apr28	May 1	-23	-20
41	County 3 Ponoka	May 21	Apr 23	Apr 26	-28	-25
42	County 29 Flagstaff	May 21	Apr 25	Apr 29	-25	-22
43	Wainwright	May 20	Apr 24	Apr 26	-26	-24
44	Provost	May 19	Apr 22	Apr 23	-27	-25
45	Special Area 4	May 20	Apr 22	Apr 23	-28	-28
46	Special Area 3	May 18	Apr 20	Apr 21	-29	-28
47	County 18 Paintearth	May 23	Apr 24	Apr 26	-29	-27
48	County 16 Stettler	May 21	Apr 24	Apr 27	-28	-25
49	County 14 Lacombe	May 17	Apr 20	Apr 24	-27	-24
51	County 17 Mountain View	May 10	Apr 18	Apr 21	-22	-19
52	Kneehill	May 15	Apr 19	Apr 23	-26	-22
53	Starland	May 18	Apr 22	Apr 24	-26	-24
54	Special Area 2	May 16	Apr 19	Apr 21	-28	-26
55	Acadia Valley	May 16	Apr 16	Apr 18	-30	-28
56	Municipal District 7	May 16	Apr 17	Apr 25	-29	-21
57	County 16 Wheatland	May 11	Apr 15	Apr 21	-26	-20
58	Rocky View	May 11	Apr 17	Apr 19	-24	-21
59	Bighorn	May 10	Apr 19	Apr 19	-21	-21
60	Improvement District 8	May 12	Apr 23	Apr 23	-19	-1
61	Improvement District 5	May 15	Apr 21	Apr 21	-24	-24

Appendix C-V.1 (Continued)

	Regional Municipality	SN6	SN5	SN4	(SN5-SN6)	(SN4-SN6)
62	Foothill	May 13	Apr 15	Apr 19	-29	-25
63	County 2 Vulcan	May 3	Apr 6	Apr 16	-27	-17
64	County 4 Newell	May 9	Apr 11	Apr 19	-28	-20
65	Cypress	May 9	Apr 6	Apr 10	-32	-28
66	Suffield	May 10	Apr 8	Apr 12	-31	-28
67	County 8 Forty Mile	May 3	Apr 3	Apr 8	-30	-25
68	County 5 Warner	Apr 28	Mar 30	Apr 6	-29	-22
69	Taber	Apr 28	Apr 3	Apr 10	-26	-18
70	County 26 Lethbridge	Apr 30	Mar 30	Apr 5	-30	-24
71	Cardston	May 1	Apr 1	Apr 9	-29	-21
72	Willow Creek	May 8	Apr 5	Apr 11	-33	-27
73	Pincher Creek	May 9	Apr 14	Apr 19	-26	-20
75	Improvement District 6	May 18	Apr 22	Apr 24	-26	-24
76	Cold Lake Air Weapons Range	May 25	Apr 29	May 2	-26	-23
77	CFB Wainwright	May 18	Apr 23	Apr 25	-25	-23

Appendix C-V.2a: Growth duration for canola averaged by Alberta Regional Municipalities for historical (1x; SN6) and doubled (2x; SN4 and SN5) atmospheric CO_2 concentrations.

	Regional Municipality	SN6	SN5	SN4	(SN5-SN6)	(SN4-SN6)
2	Improvement District 23	98	80	80	-18	-18
3	Improvement District 22	99	81	81	-18	-18
4	Improvement District 18	99	81	80	-18	-19
5	Improvement District 17	99	84	83	-15	-16
6	Improvement District 21	99	82	81	-17	-18
7	Improvement District 20	100	84	82	-16	-18
8	Fairview	99	80	80	-19	-19
9	Peace	98	80	80	-18	-18
10	Spirit River	99	80	79	-19	-20
11	Improvement District 19	98	79	78	-19	-20
12	Smoky River	98	79	79	-19	-19
13	County 1 Grande Prairie	100	85	83	-15	-17
14	Improvement District 16	99	89	87	-10	-12
15	Improvement District 15	100	89	87	-11	-13
16	County 12 Athabasca	99	81	79	-18	-20
17	County 11 Barrhead	100	84	81	-16	-19
18	Westlock	99	81	79	-18	-20
19	County 7 Thorhild	98	78	76	-20	-22
20	County 13 Smoky Lake	98	77	76	-21	-22
21	County 19 St. Paul	97	78	76	-19	-21
22	Bonnyville	97	79	77	-18	-20
23	County 21 Two Hills	96	76	75	-20	-21
24	County 24 Vermilion River	94	77	76	-17	-18
25	County 27Minburn	95	76	75	-19	-20
26	County 9 Beaver	95	76	74	-19	-21
27	County 30 Lamont	97	75	74	-22	-23
28	Improvement District 13	96	75	74	-21	-22
29	County 20 Strathcona	95	75	74	-20	-21
30	Sturgeon	96	77	76	-19	-20
31	County 28 Lac Ste. Anne	99	85	82	-14	-17
32	County 31 Parkland	99	82	80	-17	-19
33	Improvement District 14	98	93	92	-5	-6
36	Clearwater	97	94	93	-3	-4
37	Brazeau	99	89	87	-10	-12
38	County 25 Leduc	97	79	78	-18	-19
39	County 10 Wetaskiwin	97	83	81	-14	-16
40	County 22 Camrose	94	76	75	-18	-19
41	County 3 Ponoka	98	83	82	-15	-16
42	County 29 Flagstaff	93	76	75	-17	-18
43	Wainwright	93	78	76	-15	-17
44	Provost	91	78	77	-13	-14
45	Special Area 4	90	77	77	-13	-13
46	Special Area 3	87	76	75	-11	-12
47	County 18 Paintearth	92	77	76	-15	-16
48	County 16 Stettler	93	78	76	-15	-17
49	County 14 Lacombe	97	85	83	-12	-14
51	County 17 Mountain View	97	90	88	-7	-9
52	Kneehill	94	81	79	-13	-15
53	Starland	91	77	77	-14	-14
54	Special Area 2	88	76	75	-12	-13
55	Acadia Valley	83	74	73	-9	-10
57	County 16 Wheatland	93	81	77	-12	-16
58	Rocky View	97	90	87	-7	-10
59	Bighorn	96	95	94	-1	-2
60	Improvement District 8	96	94	93	-2	-3
61	Improvement District 5	97	95	94	-2	-3
62	Foothill	98	92	90	-6	-8
63	County 2 Vulcan	94	83	78	-11	-16
64	County 4 Newell	89	77	73	-12	-16

Appendix C-V.2a (Continued)

	Regional Municipality	SN6	SN5	SN4	(SN5-SN6)	(SN4-SN6)
65	Cypress	87	79	77	-8	-10
66	Suffield	85	77	74	-8	-11
67	County 8 Forty Mile	90	80	77	-10	-13
68	County 5 Warner	93	84	79	-9	-14
69	Taber	92	80	75	-12	-17
70	County 26 Lethbridge	94	83	79	-11	-15
71	Cardston	95	88	84	-7	-11
72	Willow Creek	97	91	87	-6	-10
73	Pincher Creek	96	92	90	-4	-6
75	Improvement District 6	97	94	92	-3	-5
76	Cold Lake Air WeaponsRange	98	80	79	-18	-19
77	CFB Wainwright	93	78	76	-15	-17

Appendix C-V.2b: Growth duration for spring wheat averaged by Alberta Regional Municipalities for historical (1x; SN6) and doubled (2x; SN4 and SN5) atmospheric CO_2 concentrations.

	Regional Municipality	SN6	SN5	SN4	(SN5-SN6)	(SN4-SN6)
2	Improvement District 23	104	86	85	-18	-19
3	Improvement District 22	104	86	86	-18	-18
4	Improvement District 18	103	86	85	-17	-18
5	Improvement District 17	105	88	88	-17	-17
6	Improvement District 21	105	87	86	-18	-19
7	Improvement District 20	106	88	87	-18	-19
8	Fairview	103	85	85	-18	-18
9	Peace	103	85	85	-18	-18
10	Spirit River	103	85	85	-18	-18
11	Improvement District 19	102	84	84	-18	-18
12	Smoky River	102	84	85	-18	-17
13	County 1 Grande Prairie	106	89	88	-17	-18
14	Improvement District 16	107	93	92	-14	-15
15	Improvement District 15	107	93	91	-14	-16
16	County 12 Athabasca	102	86	84	-16	-18
17	County 11 Barrhead	104	89	86	-15	-18
18	Westlock	102	86	85	-16	-17
19	County 7 Thorhild	101	83	82	-18	-19
20	County 13 Smoky Lake	101	83	82	-18	-19
21	County 19 St. Paul	100	83	82	-17	-18
22	Bonnyville	100	84	83	-16	-17
23	County 21 Two Hills	99	82	81	-17	-18
24	County 24 Vermilion River	97	82	82	-15	-15
25	County 27 Minburn	98	81	81	-17	-17
26	County 9 Beaver	97	81	80	-16	-17
27	County 30 Lamont	99	81	80	-18	-19
28	Improvement District 13	98	81	80	-17	-18
29	County 20 Strathcona	98	81	80	-17	-18
30	Sturgeon	99	83	82	-16	-17
31	County 28 Lac Ste. Anne	104	90	88	-14	-16
32	County 31 Parkland	102	88	86	-14	-16
33	Improvement District 14	108	98	97	-10	-11
36	Clearwater	107	102	101	-5	-6
37	Brazeau	106	94	93	-12	-13
38	County 25 Leduc	100	85	84	-15	-16
39	County 10 Wetaskiwin	102	88	86	-14	-16
40	County 22 Camrose	97	82	81	-15	-16
41	County 3 Ponoka	102	88	87	-14	-15
42	County 29 Flagstaff	95	82	81	-13	-14
43	Wainwright	95	83	82	-12	-13
44	Provost	94	83	82	-11	-12
45	Special Area 4	93	82	82	-11	-11
46	Special Area 3	90	80	80	-10	-10
47	County 18 Paintearth	94	82	82	-12	-12
48	County 16 Stettler	96	83	82	-13	-14
49	County 14 Lacombe	102	90	89	-12	-13
51	County 17 Mountain View	105	95	93	-10	-12
52	Kneehill	98	86	84	-12	-14
53	Starland	94	83	82	-11	-12
54	Special Area 2	91	81	80	-10	-11
55	Acadia Valley	87	78	78	-9	-9
57	County 16 Wheatland	97	85	83	-12	-14
58	Rocky View	105	95	94	-10	-11
59	Bighorn	107	102	101	-5	-6
60	Improvement District 8	107	102	101	-5	-6
61	Improvement District 5	107	104	103	-3	-4
62	Foothill	106	98	95	-8	-11
63	County 2 Vulcan	100	87	83	-13	-17
64	County 4 Newell	93	82	79	-11	-14

Appendix C-V.2b (Continued)

	Regional Municipality	SN6	SN5	SN4	(SN5-SN6)	(SN4-SN6)
65	Cypress	92	84	81	-8	-11
66	Suffield	89	81	79	-8	-10
67	County 8 Forty Mile	94	85	82	-9	-12
68	County 5 Warner	99	89	84	-10	-15
69	Taber	97	84	80	-13	-17
70	County 26 Lethbridge	99	88	85	-11	-14
71	Cardston	103	93	89	-10	-14
72	Willow Creek	105	96	93	-9	-12
73	Pincher Creek	106	96	93	-10	-13
75	Improvement District 6	107	98	97	-9	-10
76	Cold Lake Air Weapons Range	101	85	84	-16	-17
77	CFB Wainwright	96	83	82	-13	-14

Appendix C-V.2c: Growth duration for winter wheat averaged by Alberta Regional Municipalities for historical (1x; SN6) and doubled (2x; SN4 and SN5) atmospheric CO_2 concentrations.

	Regional Municipality	SN6	SN5	SN4	(SN5-SN6)	(SN4-SN6)
2	Improvement District 23	141	134	122	-7	-19
3	Improvement District 22	143	137	126	-6	-17
4	Improvement District 18	142	138	128	-4	-14
5	Improvement District 17	148	142	132	-6	-16
6	Improvement District 21	146	141	131	-5	-15
7	Improvement District 20	150	143	134	-7	-16
8	Fairview	144	141	131	-3	-13
9	Peace	142	140	129	-2	-13
10	Spirit River	145	141	132	-4	-13
11	Improvement District 19	142	140	130	-2	-12
12	Smoky River	141	140	130	-1	-11
13	County 1 Grande Prairie	152	145	135	-7	-17
14	Improvement District 16	160	149	139	-11	-21
15	Improvement District 15	158	148	138	-10	-20
16	County 12 Athabasca	143	139	129	-4	-14
17	County 11 Barrhead	148	143	133	-5	-15
18	Westlock	144	141	131	-3	-13
19	County 7 Thorhild	141	138	128	-3	-13
20	County 13 Smoky Lake	139	137	126	-2	-13
21	County 19 St. Paul	137	135	125	-2	-12
22	Bonnyville	138	136	126	-2	-12
23	County 21 Two Hills	136	135	125	-1	-11
24	County 24 Vermilion River	133	135	125	2	-8
25	County 27 Minburn	135	136	126	1	-9
26	County 9 Beaver	136	137	128	1	-8
27	County 30 Lamont	137	136	126	-1	-11
28	Improvement District 13	138	138	128	0	-10
29	County 20 Strathcona	139	138	129	-1	-10
30	Sturgeon	141	140	130	-1	-11
31	County 28 Lac Ste. Anne	149	145	135	-4	-14
32	County 31 Parkland	146	145	135	-1	-11
33	Improvement District 14	167	156	147	-11	-20
36	Clearwater	166	163	155	-3	-11
37	Brazeau	156	151	142	-5	-14
38	County 25 Leduc	143	143	134	0	-9
39	County 10 Wetaskiwin	147	146	137	-1	-10
40	County 22 Camrose	139	141	131	2	-8
41	County 3 Ponoka	147	147	138	0	-9
42	County 29 Flagstaff	135	139	130	4	-5
43	Wainwright	133	137	127	4	-6
44	Provost	132	137	128	5	-4
45	Special Area 4	132	136	127	4	-5
46	Special Area 3	131	136	127	5	-4
47	County 18 Paintearth	135	139	130	4	-5
48	County 16 Stettler	138	142	133	4	-5
49	County 14 Lacombe	147	147	139	0	-8
51	County 17 Mountain View	157	152	146	-5	-11
52	Kneehill	142	144	136	2	-6
53	Starland	137	141	133	4	-4
54	Special Area 2	133	137	129	4	-4
55	Acadia Valley	129	134	126	5	-3
57	County 16 Wheatland	141	142	135	1	-6
58	Rocky View	158	152	146	-6	-12
59	Bighorn	170	157	156	-13	-14
60	Improvement District 8	169	157	155	-12	-14
61	Improvement District 5	182	161	160	-21	-22
62	Foothill	166	153	147	-13	-19
63	County 2 Vulcan	146	140	133	-6	-13

Appendix C-V.2c (Continued)

	Regional Municipality	SN6	SN5	SN4	(SN5-SN6)	(SN4-SN6)
64	County 4 Newell	137	137	130	0	-7
65	Cypress	137	137	132	0	-5
66	Suffield	134	135	129	1	-5
67	County 8 Forty Mile	141	134	132	-7	-9
68	County 5 Warner	147	133	133	-14	-14
69	Taber	143	135	130	-8	-13
70	County 26 Lethbridge	149	136	132	-13	-17
71	Cardston	155	136	137	-19	-18
72	Willow Creek	161	144	140	-17	-21
73	Pincher Creek	166	146	146	-20	-20
75	Improvement District 6	172	153	151	-19	-21
76	Cold LakeAir WeaponsRange	139	137	127	-2	-12
77	CFB Wainwright	134	137	128	3	-6

Appendix C-V.2d: Growth duration for corn averaged by Alberta Regional Municipalities for historical (1x; SN6) and doubled (2x; SN4 and SN5) atmospheric CO_2 concentrations. 0 represents areas without sufficient heat for corn to growth under currrent climate.

	Regional Municipality	SN6	SN5	SN4	(SN5-SN6)	(SN4-SN6)
4	Improvement District 18	0	104	103	0	0
5	Improvement District 17	0	114	113	0	0
7	Improvement District 20	0	112	111	0	0
10	Spirit River	0	109	108	0	0
11	Improvement District 19	0	109	108	0	0
13	County 1 Grande Prairie	0	111	110	0	0
14	Improvement District 16	0	118	117	0	0
15	Improvement District 15	0	116	115	0	0
16	County 12 Athabasca	0	100	100	0	0
17	County 11 Barrhead	0	105	103	0	0
18	Westlock	0	101	100	0	0
19	County 7 Thorhild	0	95	95	0	0
20	County 13 Smoky Lake	0	95	94	0	0
21	County 19 St. Paul	0	95	94	0	0
23	County 21 Two Hills	0	94	93	0	0
24	County 24 Vermilion River	0	94	93	0	0
25	County 27 Minburn	0	93	92	0	0
26	County 9 Beaver	0	92	92	0	0
27	County 30 Lamont	0	92	92	0	0
28	Improvement District 13	0	93	92	0	0
29	County 20 Strathcona	0	93	92	0	0
30	Sturgeon	0	95	94	0	0
31	County 28 Lac Ste. Anne	0	105	104	0	0
32	County 31 Parkland	0	102	100	0	0
33	Improvement District 14	0	119	118	0	0
36	Clearwater	0	120	118	0	0
37	Brazeau	0	111	110	0	0
38	County 25 Leduc	0	98	97	0	0
39	County 10 Wetaskiwin	0	102	100	0	0
40	County 22 Camrose	0	94	93	0	0
41	County 3 Ponoka	0	102	101	0	0
42	County 29 Flagstaff	0	93	92	0	0
43	Wainwright	0	94	93	0	0
44	Provost	0	94	93	0	0
45	Special Area 4	0	93	92	0	0
46	Special Area 3	111	90	89	-21	-22
47	County 18 Paintearth	0	94	93	0	0
48	County 16 Stettler	0	95	94	0	0
49	County 14 Lacombe	0	104	103	0	0
51	County 17 Mountain View	0	113	111	0	0
52	Kneehill	115	98	96	-17	-19
53	Starland	116	93	92	-23	-24
54	Special Area 2	112	91	90	-21	-22
55	Acadia Valley	106	87	86	-19	-20
57	County 16 Wheatland	117	96	93	-21	-24
58	Rocky View	0	110	109	0	0
59	Bighorn	0	125	124	0	0
60	Improvement District 8	0	122	121	0	0
61	Improvement District 5	0	116	114	0	0
62	Foothill	0	111	109	0	0
63	County 2 Vulcan	108	98	93	-10	-15
64	County 4 Newell	107	92	88	-15	-19
65	Cypress	108	93	89	-15	-19
66	Suffield	101	90	87	-11	-14
67	County 8 Forty Mile	112	93	90	-19	-22
68	County 5 Warner	114	96	93	-18	-21
69	Taber	114	92	88	-22	-26
70	County 26 Lethbridge	117	97	93	-20	-24

Appendix C-V.2d (Continued)

	Regional Municipality	SN6	SN5	SN4	(SN5-SN6)	(SN4-SN6)
71	Cardston	114	104	99	-10	-15
72	Willow Creek	0	109	105	0	0
73	Pincher Creek	0	112	109	0	0
75	Improvement District 6	0	116	114	0	0
77	CFB Wainwright	0	94	93	0	0

Appendix C-VI.1a: Dryland canola yield (g/m^2) averaged by Alberta Regional Municipalities for historical (1x; SN6) and doubled (2x; SN4 and SN5) atmospheric CO_2 concentrations.

	Regional Municipality	SN6	SN5	SN4	SN5/SN6	SN4/SN6
2	Improvement District 23	200	251	241	1.26	1.21
3	Improvement District 22	217	275	262	1.27	1.21
4	Improvement District 18	233	266	259	1.14	1.11
5	Improvement District 17	218	281	261	1.29	1.2
6	Improvement District 21	225	294	280	1.3	1.24
7	Improvement District 20	221	288	273	1.31	1.24
8	Fairview	233	287	275	1.23	1.18
9	Peace	232	287	262	1.24	1.13
10	Spirit River	236	283	273	1.2	1.15
11	Improvement District 19	233	280	263	1.2	1.13
12	Smoky River	235	289	266	1.23	1.13
13	County 1 Grande Prairie	209	280	272	1.34	1.3
14	Improvement District 16	178	274	263	1.53	1.47
15	Improvement District 15	202	294	266	1.45	1.31
16	County 12 Athabasca	237	256	258	1.08	1.09
17	County 11Barrhead	248	290	279	1.17	1.13
18	Westlock	254	291	287	1.14	1.13
19	County 7 Thorhild	259	277	281	1.07	1.08
20	County 13 Smoky Lake	249	275	276	1.1	1.11
21	County 19 St. Paul	249	273	272	1.1	1.09
22	Bonnyville	243	246	263	1.02	1.08
23	County 21 Two Hills	243	258	268	1.06	1.1
24	County 24 Vermilion River	264	291	289	1.1	1.09
25	County 27 Minburn	263	280	283	1.07	1.08
26	County 9 Beaver	263	285	288	1.08	1.09
27	County 30 Lamont	265	285	290	1.07	1.09
28	Improvement District 13	267	286	291	1.07	1.09
29	County 20 Strathcona	270	289	292	1.07	1.08
30	Sturgeon	274	292	294	1.07	1.07
31	County 28 Lac Ste. Anne	251	294	275	1.17	1.1
32	County 31 Parkland	258	293	284	1.14	1.1
33	Improvement District 14	162	278	248	1.72	1.53
36	Clearwater	132	250	243	1.89	1.84
37	Brazeau	213	284	271	1.34	1.27
38	County 25 Leduc	264	294	287	1.11	1.09
39	County 10 Wetaskiwin	251	297	286	1.18	1.14
40	County 22 Camrose	258	287	287	1.11	1.11
41	County 3 Ponoka	250	297	289	1.19	1.16
42	County 29 Flagstaff	259	282	288	1.09	1.11
43	Wainwright	256	275	286	1.07	1.12
44	Provost	223	227	265	1.02	1.19
45	Special Area 4	174	181	263	1.04	1.51
46	Special Area 3	125	136	252	1.09	2.02
47	County 18 Paintearth	229	240	275	1.05	1.2
48	County 16 Stettler	249	272	284	1.09	1.14
49	County 14 Lacombe	242	296	292	1.22	1.2
51	County 17 Mountain View	199	292	291	1.46	1.46
52	Kneehill	228	259	291	1.14	1.28
53	Starland	209	224	281	1.07	1.35
54	Special Area 2	138	149	245	1.08	1.78
55	Acadia Valley	111	122	228	1.1	2.04
57	County 16 Wheatland	185	222	284	1.2	1.54
58	Rocky View	192	294	290	1.53	1.51
59	Bighorn	130	276	271	2.12	2.08
60	Improvement District 8	136	275	269	2.02	1.98
61	Improvement District 5	92	235	232	2.54	2.5
62	Foothill	168	282	279	1.67	1.66
63	County 2 Vulcan	162	207	280	1.28	1.72
64	County 4 Newell	128	144	247	1.13	1.93

Appendix C-VI.1a (Continued)

	Regional Municipality	SN6	SN5	SN4	SN5/SN6	SN4/SN6
65	Cypress	122	151	246	1.24	2.01
66	Suffield	107	123	224	1.15	2.09
67	County 8 Forty Mile	124	151	259	1.21	2.07
68	County 5 Warner	142	187	278	1.31	1.95
69	Taber	136	155	268	1.14	1.96
70	County 26 Lethbridge	154	188	276	1.22	1.79
71	Cardston	173	254	289	1.46	1.67
72	Willow Creek	162	250	277	1.54	1.71
73	Pincher Creek	154	271	278	1.75	1.8
75	Improvement District 6	133	260	262	1.96	1.97
76	Cold LakeAir WeaponsRange	253	270	271	1.07	1.07
77	CFB Wainwright	245	252	273	1.02	1.11

Appendix C-VI.1b: Dryland spring wheat yields (g/m^2) averaged by Alberta Regional Municipalities for historical (1x; SN6) and doubled (2x; SN4 and SN5) atmospheric CO_2 concentrations.

	Regional Municipality	SN6	SN5	SN4	SN5/SN6	SN4/SN6
2	Improvement District 23	120	143	146	1.19	1.21
3	Improvement District 22	130	159	161	1.22	1.24
4	Improvement District 18	124	145	149	1.17	1.2
5	Improvement District 17	126	152	155	1.21	1.23
6	Improvement District 21	131	162	164	1.24	1.25
7	Improvement District 20	128	157	158	1.23	1.23
8	Fairview	134	166	166	1.24	1.24
9	Peace	132	161	163	1.22	1.24
10	Spirit River	136	168	168	1.24	1.24
11	Improvement District 19	132	161	161	1.22	1.22
12	Smoky River	130	158	160	1.21	1.22
13	County 1 Grande Prairie	135	169	168	1.25	1.25
14	Improvement District 16	123	154	153	1.25	1.24
15	Improvement District 15	122	147	149	1.21	1.22
16	County 12 Athabasca	125	146	149	1.17	1.2
17	County 11 Barrhead	130	154	157	1.19	1.21
18	Westlock	133	160	164	1.2	1.23
19	County 7 Thorhild	134	164	168	1.22	1.26
20	County 13 Smoky Lake	138	171	175	1.24	1.27
21	County 19 St. Paul	134	164	169	1.22	1.26
22	Bonnyville	127	150	155	1.18	1.22
23	County 21Two Hills	145	184	190	1.26	1.31
24	County 24 Vermilion River	144	183	188	1.28	1.31
25	County 27 Minburn	148	189	192	1.28	1.3
26	County 9 Beaver	151	196	197	1.3	1.31
27	County 30 Lamont	157	210	210	1.33	1.33
28	Improvement District 13	156	205	206	1.31	1.32
29	County 20 Strathcona	154	199	200	1.3	1.3
30	Sturgeon	147	185	188	1.26	1.28
31	County 28 Lac Ste. Anne	130	155	157	1.19	1.21
32	County 31 Parkland	137	166	169	1.21	1.23
33	Improvement District 14	116	146	146	1.26	1.26
36	Clearwater	103	142	142	1.38	1.38
37	Brazeau	126	150	152	1.2	1.21
38	County 25 Leduc	146	183	185	1.25	1.27
39	County 10 Wetaskiwin	144	180	181	1.25	1.26
40	County 22 Camrose	153	197	198	1.29	1.3
41	County 3 Ponoka	142	179	181	1.26	1.27
42	County 29 Flagstaff	146	187	192	1.28	1.31
43	Wainwright	138	175	181	1.27	1.32
44	Provost	128	154	163	1.2	1.27
45	Special Area 4	117	140	158	1.2	1.35
46	Special Area 3	101	123	156	1.21	1.54
47	County 18 Paintearth	133	166	174	1.25	1.31
48	County 16 Stettler	141	178	184	1.27	1.31
49	County 14 Lacombe	141	179	182	1.27	1.29
51	County 17 Mountain View	132	174	175	1.32	1.33
52	Kneehill	142	182	186	1.28	1.31
53	Starland	138	177	185	1.29	1.35
54	Special Area 2	106	132	158	1.24	1.48
55	Acadia Valley	97	117	157	1.21	1.62
57	County 16 Wheatland	125	165	175	1.31	1.39
58	Rocky View	133	181	183	1.36	1.38
59	Bighorn	115	166	166	1.45	1.44
60	Improvement District 8	114	164	164	1.43	1.43
61	Improvement District 5	100	160	158	1.6	1.58
62	Foothill	128	180	181	1.41	1.42
63	County 2 Vulcan	119	157	171	1.33	1.44

Appendix C-VI.1b (Continued)

	Regional Municipality	SN6	SN5	SN4	SN5/SN6	SN4/SN6
64	County 4 Newell	101	134	157	1.34	1.55
65	Cypress	102	136	172	1.33	1.68
66	Suffield	94	122	167	1.29	1.77
67	County 8 Forty Mile	108	147	176	1.35	1.62
68	County 5 Warner	116	158	175	1.36	1.5
69	Taber	108	141	165	1.31	1.53
70	County 26 Lethbridge	117	155	171	1.33	1.47
71	Cardston	131	178	179	1.35	1.36
72	Willow Creek	126	171	174	1.35	1.37
73	Pincher Creek	129	177	174	1.37	1.35
75	Improvement District 6	124	172	170	1.39	1.37
76	Cold Lake Air Weapons Range	125	147	151	1.17	1.21
77	CFB Wainwright	136	168	175	1.24	1.29

Appendix C-VI.1c: Dryland corn yields (g/m^2) averaged by Alberta Regional Municipalities for historical (1x; SN6) and doubled (2x; SN4 and SN5) atmospheric CO_2 concentrations. 0 represents areas without sufficient heat for corn to growth under current climate.

	Regional Municipality	SN6	SN5	SN4	SN5/SN6	SN4/SN6
4	Improvement District 18	0	635	796	0	0
5	Improvement District 17	0	738	810	0	0
7	Improvement District 20	0	612	689	0	0
10	Spirit River	0	597	681	0	0
11	Improvement District 19	0	612	691	0	0
13	County 1 Grande Prairie	0	605	677	0	0
14	Improvement District 16	0	683	729	0	0
15	Improvement District 15	0	775	832	0	0
16	County 12 Athabasca	0	617	810	0	0
17	County 11Barrhead	0	667	792	0	0
18	Westlock	0	637	824	0	0
19	County 7 Thorhild	0	564	806	0	0
20	County 13 Smoky Lake	0	525	764	0	0
21	County 19 St. Paul	0	501	744	0	0
23	County 21 Two Hills	0	483	695	0	0
24	County 24 Vermilion River	0	459	706	0	0
25	County 27 Minburn	0	480	718	0	0
26	County 9 Beaver	0	482	730	0	0
27	County 30 Lamont	0	512	769	0	0
28	Improvement District 13	0	526	767	0	0
29	County 20 Strathcona	0	538	772	0	0
30	Sturgeon	0	566	789	0	0
31	County 28 Lac Ste. Anne	0	703	819	0	0
32	County 31 Parkland	0	678	819	0	0
33	Improvement District 14	0	757	808	0	0
36	Clearwater	0	717	802	0	0
37	Brazeau	0	739	818	0	0
38	County 25 Leduc	0	626	801	0	0
39	County 10 Wetaskiwin	0	662	807	0	0
40	County 22 Camrose	0	510	730	0	0
41	County 3 Ponoka	0	611	785	0	0
42	County 29 Flagstaff	0	434	688	0	0
43	Wainwright	0	418	649	0	0
44	Provost	0	350	537	0	0
45	Special Area 4	0	274	464	0	0
46	Special Area 3	178	214	365	1.2	2.05
47	County 18 Paintearth	0	367	596	0	0
48	County 16 Stettler	0	416	652	0	0
49	County 14 Lacombe	0	557	742	0	0
51	County 17 Mountain View	0	572	717	0	0
52	Kneehill	236	412	614	1.74	2.6
53	Starland	247	344	563	1.39	2.27
54	Special Area 2	196	237	398	1.21	2.03
55	Acadia Valley	166	185	331	1.12	1.99
57	County 16 Wheatland	234	311	518	1.33	2.21
58	Rocky View	0	466	652	0	0
59	Bighorn	0	583	715	0	0
60	Improvement District 8	0	592	723	0	0
61	Improvement District 5	0	468	620	0	0
62	Foothill	0	416	590	0	0
63	County 2 Vulcan	211	290	470	1.38	2.22
64	County 4 Newell	202	224	388	1.11	1.92
65	Cypress	163	231	410	1.41	2.51
66	Suffield	159	190	351	1.19	2.2
67	County 8 Forty Mile	179	233	426	1.3	2.37
68	County 5 Warner	196	293	469	1.49	2.39
69	Taber	200	238	420	1.19	2.1
70	County 26 Lethbridge	218	295	460	1.35	2.1

Appendix C-VI.1c (Continued)

	Regional Municipality	SN6	SN5	SN4	SN5/SN6	SN4/SN6
71	Cardston	206	420	549	2.03	2.66
72	Willow Creek	0	390	529	0	0
73	Pincher Creek	0	429	535	0	0
75	Improvement District 6	0	433	533	0	0
77	CFB Wainwright	0	409	602	0	0

Appendix C-VI.1d: Dryland crested wheatgrass yields (g/m^2) averaged by Alberta Regional Municipalities for historical (1x; SN6) and doubled (2x; SN4 and SN5) atmospheric CO_2 concentrations.

	Regional Municipality	SN6	SN5	SN4	SN5/SN6	SN4/SN6
2	Improvement District 23	361	317	364	0.88	1.01
3	Improvement District 22	398	401	446	1.01	1.12
4	Improvement District 18	435	520	619	1.19	1.42
5	Improvement District 17	428	606	662	1.42	1.54
6	Improvement District 21	417	490	522	1.17	1.25
7	Improvement District 20	433	560	550	1.29	1.27
8	Fairview	429	483	524	1.13	1.22
9	Peace	409	379	436	0.93	1.07
10	Spirit River	449	513	531	1.14	1.18
11	Improvement District 19	416	385	423	0.93	1.02
12	Smoky River	411	383	452	0.93	1.1
13	County 1 Grande Prairie	437	561	544	1.28	1.25
14	Improvement District 16	406	667	657	1.64	1.62
15	Improvement District 15	438	828	830	1.89	1.89
16	County 12 Athabasca	448	545	667	1.22	1.49
17	County 11 Barrhead	479	673	730	1.41	1.52
18	Westlock	484	668	746	1.38	1.54
19	County 7 Thorhild	485	589	716	1.21	1.48
20	County 13 Smoky Lake	450	516	659	1.15	1.47
21	County 19 St. Paul	426	506	631	1.19	1.48
22	Bonnyville	413	457	573	1.11	1.39
23	County 21 Two Hills	394	436	570	1.11	1.45
24	County 24 Vermilion River	402	493	584	1.23	1.45
25	County 27 Minburn	412	462	580	1.12	1.41
26	County 9 Beaver	417	470	579	1.13	1.39
27	County 30 Lamont	454	506	645	1.11	1.42
28	Improvement District 13	455	513	635	1.13	1.39
29	County 20 Strathcona	460	535	648	1.16	1.41
30	Sturgeon	485	607	700	1.25	1.44
31	County 28 Lac Ste. Anne	508	752	783	1.48	1.54
32	County 31 Parkland	526	690	739	1.31	1.41
33	Improvement District 14	398	872	859	2.19	2.15
36	Clearwater	331	797	780	2.41	2.36
37	Brazeau	486	798	826	1.64	1.7
38	County 25 Leduc	502	634	700	1.26	1.39
39	County 10 Wetaskiwin	497	704	747	1.41	1.5
40	County 22 Camrose	419	502	590	1.2	1.41
41	County 3 Ponoka	486	707	758	1.46	1.56
42	County 29 Flagstaff	377	465	559	1.23	1.48
43	Wainwright	367	469	547	1.28	1.49
44	Provost	305	363	444	1.19	1.46
45	Special Area 4	258	300	374	1.17	1.45
46	Special Area 3	192	238	295	1.24	1.53
47	County 18 Paintearth	324	383	470	1.18	1.45
48	County 16 Stettler	372	476	557	1.28	1.5
49	County 14 Lacombe	475	694	738	1.46	1.55
51	County 17 Mountain View	460	768	779	1.67	1.69
52	Kneehill	414	490	531	1.18	1.28
53	Starland	326	336	430	1.03	1.32
54	Special Area 2	215	243	295	1.13	1.37
55	Acadia Valley	149	227	261	1.52	1.75
57	County 16 Wheatland	357	402	398	1.13	1.12
58	Rocky View	455	686	690	1.51	1.52
59	Bighorn	346	814	817	2.35	2.36
60	Improvement District 8	355	805	805	2.27	2.26
61	Improvement District 5	242	650	651	2.69	2.69
62	Foothill	425	644	626	1.51	1.47

Appendix C-VI.1d (Continued)

	Regional Municipality	SN6	SN5	SN4	SN5/SN6	SN4/SN6
63	County 2 Vulcan	397	457	395	1.15	0.99
64	County 4 Newell	232	303	297	1.31	1.28
65	Cypress	212	380	403	1.79	1.89
66	Suffield	169	322	352	1.9	2.08
67	County 8 Forty Mile	273	456	458	1.67	1.68
68	County 5 Warner	380	579	506	1.52	1.33
69	Taber	362	491	463	1.35	1.28
70	County 26 Lethbridge	409	565	532	1.38	1.3
71	Cardston	458	585	478	1.28	1.04
72	Willow Creek	433	605	564	1.4	1.3
73	Pincher Creek	439	546	497	1.24	1.13
75	Improvement District 6	374	545	529	1.46	1.41
76	Cold Lake Air WeaponsRange	443	533	653	1.20	1.47
77	CFB Wainwright	355	410	497	1.16	1.4

Appendix C-VI.2a: Fallow-canola rotation yields (g/m^2) averaged by Alberta Regional Municipalities for historical (1x; SN6) and doubled (2x; SN4 and SN5) atmospheric CO_2 concentrations.

	Regional Municipality	SN6	SN5	SN4	SN5/SN6	SN4/SN6
2	Improvement District 23	201	263	271	1.31	1.35
3	Improvement District 22	217	291	297	1.34	1.37
4	Improvement District 18	254	286	305	1.13	1.2
5	Improvement District 17	235	321	332	1.37	1.41
6	Improvement District 21	223	317	324	1.42	1.45
7	Improvement District 20	221	329	337	1.49	1.53
8	Fairview	235	310	319	1.32	1.36
9	Peace	232	292	297	1.26	1.28
10	Spirit River	238	312	323	1.31	1.36
11	Improvement District 19	232	288	299	1.24	1.28
12	Smoky River	234	292	306	1.25	1.31
13	County 1 Grande Prairie	211	312	321	1.48	1.52
14	Improvement District 16	189	319	320	1.69	1.69
15	Improvement District 15	225	349	351	1.55	1.56
16	County 12 Athabasca	266	279	308	1.05	1.16
17	County 11 Barrhead	268	308	324	1.15	1.21
18	Westlock	285	322	344	1.13	1.21
19	County 7 Thorhild	287	302	326	1.05	1.14
20	County 13 Smoky Lake	268	277	302	1.04	1.13
21	County 19 St. Paul	260	265	293	1.02	1.12
22	Bonnyville	250	238	266	0.95	1.06
23	County 21 Two Hills	245	250	277	1.02	1.13
24	County 24 Vermilion River	266	279	307	1.05	1.15
25	County 27 Minburn	268	273	300	1.02	1.12
26	County 9 Beaver	275	272	302	0.99	1.1
27	County 30 Lamont	280	282	308	1.01	1.1
28	Improvement District 13	285	281	309	0.99	1.08
29	County 20 Strathcona	293	285	311	0.97	1.06
30	Sturgeon	297	299	322	1.01	1.09
31	County 28 Lac Ste. Anne	281	334	343	1.19	1.22
32	County 31 Parkland	295	331	343	1.12	1.17
33	Improvement District 14	182	343	324	1.89	1.78
36	Clearwater	144	293	277	2.04	1.93
37	Brazeau	240	336	334	1.4	1.39
38	County 25 Leduc	296	312	333	1.05	1.12
39	County 10 Wetaskiwin	283	317	336	1.12	1.19
40	County 22 Camrose	274	276	313	1.01	1.14
41	County 3 Ponoka	273	321	347	1.18	1.27
42	County 29 Flagstaff	268	274	306	1.02	1.14
43	Wainwright	257	263	303	1.02	1.18
44	Provost	230	213	255	0.93	1.11
45	Special Area 4	198	195	257	0.98	1.29
46	Special Area 3	157	167	242	1.06	1.54
47	County 18 Paintearth	245	245	293	1	1.2
48	County 16 Stettler	257	268	316	1.05	1.23
49	County 14 Lacombe	256	318	343	1.24	1.34
51	County 17 Mountain View	206	319	328	1.55	1.59
52	Kneehill	243	276	318	1.13	1.31
53	Starland	235	256	306	1.09	1.3
54	Special Area 2	169	180	246	1.07	1.45
55	Acadia Valley	142	155	227	1.1	1.6
57	County 16 Wheatland	207	239	301	1.16	1.45
58	Rocky View	195	296	310	1.51	1.59
59	Bighorn	133	297	271	2.24	2.04
60	Improvement District 8	141	298	280	2.12	1.99
61	Improvement District 5	109	231	217	2.13	2
62	Foothill	171	280	290	1.64	1.69

Appendix C-VI.2a (Continued).

	Regional Municipality	SN6	SN5	SN4	SN5/SN6	SN4/SN6
63	County 2 Vulcan	181	219	277	1.21	1.53
64	County 4 Newell	164	179	245	1.09	1.49
65	Cypress	161	197	268	1.22	1.66
66	Suffield	144	163	236	1.13	1.63
67	County 8 Forty Mile	167	199	270	1.19	1.62
68	County 5 Warner	168	225	283	1.34	1.69
69	Taber	177	201	261	1.14	1.47
70	County 26 Lethbridge	177	225	265	1.27	1.49
71	Cardston	174	276	308	1.59	1.77
72	Willow Creek	161	258	275	1.6	1.71
73	Pincher Creek	153	280	305	1.83	2
75	Improvement District 6	136	262	276	1.94	2.03
76	Cold Lake Air WeaponsRange	271	273	298	1.00	1.10
77	CFB Wainwright	248	238	271	0.96	1.09

Appendix C-VI.2b: Fallow-spring wheat rotation yields (g/m^2) averaged by Alberta Regional Municipalities for historical (1x; SN6) and doubled (2x; SN4 and SN5) atmospheric CO_2 concentrations.

	Regional Municipality	SN6	SN5	SN4	SN5/SN6	SN4/SN6
2	Improvement District 23	180	216	210	1.2	1.16
3	Improvement District 22	201	246	240	1.23	1.2
4	Improvement District 18	182	214	209	1.17	1.14
5	Improvement District 17	189	230	221	1.22	1.17
6	Improvement District 21	202	252	246	1.24	1.22
7	Improvement District 20	193	239	230	1.24	1.19
8	Fairview	206	254	245	1.23	1.19
9	Peace	203	246	240	1.21	1.18
10	Spirit River	209	257	244	1.23	1.17
11	Improvement District 19	200	241	229	1.21	1.15
12	Smoky River	198	240	232	1.21	1.17
13	County 1 Grande Prairie	205	256	240	1.25	1.17
14	Improvement District 16	178	220	205	1.23	1.15
15	Improvement District 15	175	214	199	1.22	1.14
16	County 12 Athabasca	182	209	204	1.15	1.12
17	County 11 Barrhead	192	225	215	1.17	1.12
18	Westlock	202	242	234	1.2	1.16
19	County 7 Thorhild	206	246	241	1.2	1.17
20	County 13 Smoky Lake	213	252	251	1.19	1.18
21	County 19 St. Paul	205	243	243	1.18	1.19
22	Bonnyville	190	212	215	1.12	1.13
23	County 21 Two Hills	224	267	270	1.19	1.2
24	County 24 Vermilion River	233	288	290	1.24	1.24
25	County 27 Minburn	236	284	285	1.2	1.21
26	County 9 Beaver	244	288	289	1.18	1.19
27	County 30 Lamont	260	311	312	1.19	1.2
28	Improvement District 13	256	301	301	1.18	1.18
29	County 20 Strathcona	250	291	290	1.17	1.16
30	Sturgeon	233	274	271	1.18	1.17
31	County 28 Lac Ste. Anne	193	228	215	1.18	1.12
32	County 31 Parkland	208	245	237	1.18	1.14
33	Improvement District 14	168	213	196	1.27	1.17
36	Clearwater	152	210	194	1.38	1.28
37	Brazeau	182	222	208	1.22	1.14
38	County 25 Leduc	229	269	264	1.18	1.15
39	County 10 Wetaskiwin	224	268	261	1.19	1.16
40	County 22 Camrose	244	287	290	1.18	1.19
41	County 3 Ponoka	223	273	269	1.23	1.21
42	County 29 Flagstaff	235	283	287	1.21	1.22
43	Wainwright	220	267	275	1.22	1.25
44	Provost	194	217	228	1.12	1.18
45	Special Area 4	179	202	227	1.13	1.27
46	Special Area 3	155	179	225	1.15	1.45
47	County 18 Paintearth	210	246	254	1.17	1.21
48	County 16 Stettler	223	268	273	1.2	1.22
49	County 14 Lacombe	221	277	275	1.25	1.24
51	County 17 Mountain View	206	266	260	1.29	1.26
52	Kneehill	225	279	290	1.24	1.29
53	Starland	218	268	278	1.23	1.28
54	Special Area 2	164	193	227	1.18	1.38
55	Acadia Valley	147	172	223	1.17	1.51
57	County 16 Wheatland	194	241	265	1.25	1.36
58	Rocky View	207	276	281	1.33	1.35
59	Bighorn	174	252	233	1.45	1.34
60	Improvement District 8	173	247	232	1.43	1.34
61	Improvement District 5	142	225	207	1.58	1.46
62	Foothill	193	267	272	1.38	1.41
63	County 2 Vulcan	179	225	250	1.26	1.4

Appendix C-VI.2b (Continued).

	Regional Municipality	SN6	SN5	SN4	SN5/SN6	SN4/SN6
64	County 4 Newell	158	193	227	1.23	1.44
65	Cypress	167	213	263	1.28	1.57
66	Suffield	155	188	246	1.21	1.58
67	County 8 Forty Mile	177	223	270	1.26	1.53
68	County 5 Warner	174	229	258	1.32	1.49
69	Taber	169	208	245	1.23	1.45
70	County 26 Lethbridge	172	224	245	1.3	1.43
71	Cardston	178	251	249	1.41	1.4
72	Willow Creek	176	241	244	1.37	1.39
73	Pincher Creek	172	243	237	1.42	1.38
75	Improvement District 6	163	233	229	1.43	1.41
76	Cold Lake Air Weapons Range	186	215	213	1.15	1.14
77	CFB Wainwright	210	245	252	1.17	1.2

Appendix C-VI.2c: Fallow-winter wheat rotation yields (g/m^2) averaged by Alberta Regional Municipalities for historical (1x; SN6) and doubled (2x; SN4 and SN5) atmospheric CO_2 concentrations.

	Regional Municipality	SN6	SN5	SN4	SN5/SN6	SN4/SN6
2	Improvement District 23	186	222	223	1.19	1.2
3	Improvement District 22	212	255	248	1.2	1.17
4	Improvement District 18	200	309	300	1.55	1.5
5	Improvement District 17	216	321	297	1.49	1.38
6	Improvement District 21	222	294	257	1.33	1.16
7	Improvement District 20	214	309	270	1.44	1.27
8	Fairview	223	296	276	1.33	1.24
9	Peace	217	283	269	1.31	1.24
10	Spirit River	222	302	289	1.36	1.3
11	Improvement District 19	212	277	275	1.31	1.3
12	Smoky River	216	273	282	1.26	1.31
13	County 1 Grande Prairie	221	289	262	1.31	1.19
14	Improvement District 16	209	297	284	1.42	1.36
15	Improvement District 15	210	345	325	1.65	1.55
16	County 12 Athabasca	195	309	271	1.59	1.39
17	County 11 Barrhead	214	303	289	1.41	1.35
18	Westlock	221	366	298	1.65	1.35
19	County 7 Thorhild	220	331	318	1.51	1.45
20	County 13 Smoky Lake	232	339	321	1.46	1.39
21	County 19 St. Paul	226	318	320	1.41	1.41
22	Bonnyville	207	279	318	1.35	1.54
23	County 21 Two Hills	248	288	289	1.16	1.17
24	County 24 Vermilion River	248	304	298	1.22	1.2
25	County 27 Minburn	253	292	283	1.15	1.12
26	County 9 Beaver	258	270	279	1.04	1.08
27	County 30 Lamont	272	311	315	1.15	1.16
28	Improvement District 13	267	294	298	1.1	1.12
29	County 20 Strathcona	261	290	288	1.11	1.11
30	Sturgeon	245	286	283	1.17	1.16
31	County 28 Lac Ste. Anne	215	320	298	1.49	1.38
32	County 31 Parkland	223	276	271	1.24	1.22
33	Improvement District14	214	353	305	1.65	1.43
36	Clearwater	183	321	323	1.75	1.76
37	Brazeau	202	301	330	1.49	1.63
38	County 25Leduc	242	268	279	1.11	1.15
39	County 10Wetaskiwin	237	258	294	1.09	1.24
40	County 22Camrose	257	262	266	1.02	1.04
41	County 3 Ponoka	237	268	271	1.13	1.14
42	County 29Flagstaff	246	256	264	1.04	1.07
43	Wainwright	233	270	256	1.16	1.1
44	Provost	200	232	217	1.16	1.08
45	Special Area 4	183	227	245	1.24	1.34
46	Special Area 3	157	183	263	1.17	1.67
47	County 18 Paintearth	214	239	234	1.12	1.09
48	County 16 Stettler	229	238	240	1.04	1.05
49	County 14 Lacombe	236	261	254	1.1	1.07
51	County 17 Mountain View	251	269	268	1.07	1.07
52	Kneehill	222	253	254	1.14	1.14
53	Starland	212	238	249	1.12	1.17
54	Special Area 2	160	193	241	1.21	1.51
55	Acadia Valley	149	175	238	1.17	1.6
57	County 16 Wheatland	193	224	231	1.16	1.2
58	Rocky View	244	258	251	1.06	1.03
59	Bighorn	233	255	250	1.09	1.07
60	Improvement District 8	228	269	262	1.18	1.15
61	Improvement District 5	182	251	221	1.38	1.21
62	Foothill	213	261	251	1.22	1.17
63	County 2 Vulcan	211	217	227	1.03	1.07

Appendix C-VI.2c (Continued).

	Regional Municipality	SN6	SN5	SN4	SN5/SN6	SN4/SN6
64	County 4 Newell	165	219	231	1.32	1.4
65	Cypress	173	208	238	1.2	1.37
66	Suffield	149	183	236	1.23	1.59
67	County 8 Forty Mile	190	219	239	1.15	1.26
68	County 5 Warner	212	222	235	1.04	1.11
69	Taber	237	228	222	0.96	0.94
70	County 26 Lethbridge	239	219	230	0.92	0.97
71	Cardston	205	240	235	1.17	1.15
72	Willow Creek	202	232	243	1.15	1.2
73	Pincher Creek	197	237	239	1.2	1.21
75	Improvement District 6	195	235	238	1.2	1.22
76	Cold Lake Air Weapons Range	205	305	362	1.49	1.76
77	CFB Wainwright	219	243	238	1.11	1.09

Appendix C-VI.2d: Fallow-corn rotation yields (g/m^2) averaged by Alberta Regional Municipalities for historical (1x; SN6) and doubled (2x; SN4 and SN5) atmospheric CO_2 concentrations. 0 represents areas without sufficient heat for corn to growth under current climate.

	Regional Municipality	SN6	SN5	SN4	SN5/SN6	SN4/SN6
4	Improvement District 18	0	715	780	0	0
5	Improvement District 17	0	761	796	0	0
7	Improvement District 20	0	665	698	0	0
10	Spirit River	0	654	689	0	0
11	Improvement District 19	0	661	697	0	0
13	County 1 Grande Prairie	0	655	687	0	0
14	Improvement District 16	0	703	730	0	0
15	Improvement District 15	0	799	825	0	0
16	County 12 Athabasca	0	725	799	0	0
17	County 11Barrhead	0	709	777	0	0
18	Westlock	0	749	815	0	0
19	County 7 Thorhild	0	712	800	0	0
20	County 13 Smoky Lake	0	648	745	0	0
21	County 19 St. Paul	0	633	727	0	0
23	County 21 Two Hills	0	571	675	0	0
24	County 24 Vermilion River	0	601	696	0	0
25	County 27 Minburn	0	607	700	0	0
26	County 9 Beaver	0	610	716	0	0
27	County 30 Lamont	0	654	755	0	0
28	Improvement District 13	0	651	755	0	0
29	County 20 Strathcona	0	657	762	0	0
30	Sturgeon	0	688	782	0	0
31	County 28 Lac Ste. Anne	0	755	803	0	0
32	County 31 Parkland	0	747	805	0	0
33	Improvement District 14	0	784	806	0	0
36	Clearwater	0	760	806	0	0
37	Brazeau	0	776	814	0	0
38	County 25 Leduc	0	716	793	0	0
39	County 10 Wetaskiwin	0	741	805	0	0
40	County 22 Camrose	0	627	726	0	0
41	County 3 Ponoka	0	721	797	0	0
42	County 29 Flagstaff	0	590	690	0	0
43	Wainwright	0	546	651	0	0
44	Provost	0	442	565	0	0
45	Special Area 4	0	381	540	0	0
46	Special Area 3	280	298	487	1.06	1.74
47	County 18 Paintearth	0	508	628	0	0
48	County 16 Stettler	0	575	684	0	0
49	County 14 Lacombe	0	688	771	0	0
51	County 17 Mountain View	0	678	754	0	0
52	Kneehill	366	563	675	1.54	1.84
53	Starland	374	504	633	1.34	1.69
54	Special Area 2	293	331	501	1.13	1.71
55	Acadia Valley	257	270	462	1.05	1.79
57	County 16 Wheatland	377	452	608	1.2	1.61
58	Rocky View	0	599	699	0	0
59	Bighorn	0	660	727	0	0
60	Improvement District 8	0	672	741	0	0
61	Improvement District 5	0	565	644	0	0
62	Foothill	0	538	624	0	0
63	County 2 Vulcan	362	410	556	1.13	1.54
64	County 4 Newell	318	334	509	1.05	1.6
65	Cypress	285	376	570	1.32	2
66	Suffield	265	308	535	1.16	2.01
67	County 8 Forty Mile	317	379	586	1.2	1.85
68	County 5 Warner	339	420	583	1.24	1.72
69	Taber	344	378	566	1.1	1.65
70	County 26 Lethbridge	368	419	567	1.14	1.54

Appendix C-VI.2d (Continued)

	Regional Municipality	SN6	SN5	SN4	SN5/SN6	SN4/SN6
71	Cardston	350	494	582	1.41	1.66
72	Willow Creek	0	465	554	0	0
73	Pincher Creek	0	470	544	0	0
75	Improvement District 6	0	467	537	0	0
77	CFB Wainwright	0	498	596	0	0

Appendix C-VI.3a: Irrigated canola yields (g/m^2) averaged by Alberta Regional Municipalities for historical (1x; SN6) and doubled (2x; SN4 and SN5) atmospheric CO_2 concentrations.

	Regional Municipality	SN6	SN5	SN4	SN5/SN6	SN4/SN6
2	Improvement District 23	258	330	332	1.27	1.29
3	Improvement District 22	264	344	346	1.31	1.31
4	Improvement District 18	284	362	366	1.27	1.29
5	Improvement District 17	268	372	371	1.39	1.39
6	Improvement District 21	263	360	361	1.37	1.37
7	Improvement District 20	259	369	366	1.42	1.41
8	Fairview	277	358	357	1.29	1.29
9	Peace	278	347	349	1.25	1.25
10	Spirit River	280	359	356	1.28	1.27
11	Improvement District 19	283	347	347	1.22	1.23
12	Smoky River	281	349	351	1.24	1.25
13	County 1 Grande Prairie	255	366	362	1.43	1.42
14	Improvement District 16	227	376	372	1.66	1.64
15	Improvement District 15	248	395	384	1.59	1.55
16	County 12 Athabasca	301	371	377	1.23	1.25
17	County 11 Barrhead	303	387	389	1.28	1.28
18	Westlock	310	388	392	1.25	1.26
19	County 7 Thorhild	317	377	387	1.19	1.22
20	County 13 Smoky Lake	306	364	374	1.19	1.22
21	County 19 St. Paul	303	357	365	1.18	1.21
22	Bonnyville	297	353	360	1.19	1.21
23	County 21 Two Hills	307	351	359	1.14	1.17
24	County 24 Vermilion River	306	347	354	1.14	1.16
25	County 27 Minburn	311	352	361	1.13	1.16
26	County 9 Beaver	318	357	366	1.12	1.15
27	County 30 Lamont	319	363	373	1.14	1.17
28	Improvement District 13	324	366	376	1.13	1.16
29	County 20 Strathcona	329	370	381	1.13	1.16
30	Sturgeon	330	379	387	1.15	1.18
31	County 28 Lac Ste. Anne	306	396	394	1.29	1.29
32	County 31 Parkland	318	390	393	1.23	1.24
33	Improvement District 14	204	377	369	1.85	1.81
36	Clearwater	165	330	331	1.99	2
37	Brazeau	269	387	388	1.44	1.44
38	County 25 Leduc	325	383	389	1.18	1.2
39	County 10 Wetaskiwin	311	384	389	1.24	1.25
40	County 22 Camrose	318	361	372	1.14	1.17
41	County 3 Ponoka	304	381	387	1.25	1.27
42	County 29 Flagstaff	316	355	365	1.12	1.15
43	Wainwright	308	350	357	1.14	1.16
44	Provost	304	344	352	1.13	1.16
45	Special Area 4	303	344	350	1.14	1.16
46	Special Area 3	296	336	341	1.13	1.15
47	County 18 Paintearth	311	352	362	1.13	1.16
48	County 16 Stettler	311	354	364	1.14	1.17
49	County 14 Lacombe	294	375	381	1.28	1.3
51	County 17 Mountain View	240	372	379	1.55	1.58
52	Kneehill	302	352	359	1.16	1.19
53	Starland	308	347	357	1.13	1.16
54	Special Area 2	298	336	342	1.12	1.15
55	Acadia Valley	288	327	330	1.14	1.15
57	County 16 Wheatland	301	349	358	1.16	1.19
58	Rocky View	247	368	371	1.49	1.5
59	Bighorn	160	345	349	2.15	2.17
60	Improvement District 8	167	345	349	2.06	2.08
61	Improvement District 5	139	301	303	2.17	2.18
62	Foothill	230	368	372	1.6	1.61
63	County 2 Vulcan	292	347	358	1.19	1.22
64	County 4 Newell	297	333	342	1.12	1.15

Appendix C-VI.3a (Continued)

	Regional Municipality	SN6	SN5	SN4	SN5/SN6	SN4/SN6
65	Cypress	291	338	342	1.16	1.18
66	Suffield	290	328	333	1.13	1.14
67	County 8 Forty Mile	297	337	343	1.14	1.15
68	County 5 Warner	293	348	358	1.19	1.22
69	Taber	303	333	341	1.1	1.12
70	County 26 Lethbridge	299	342	351	1.14	1.18
71	Cardston	275	371	382	1.35	1.39
72	Willow Creek	258	368	377	1.42	1.46
73	Pincher Creek	234	393	396	1.68	1.69
75	Improvement District 6	202	376	377	1.86	1.87
76	Cold Lake Air Weapons Range	293	364	370	1.24	1.26
77	CFB Wainwright	311	350	357	1.12	1.15

Appendix C-VI.3b: Irrigated spring wheat yields (g/m^2) averaged by Alberta Regional Municipalities for historical (1x; SN6) and doubled (2x; SN4 and SN5) atmospheric CO_2 concentrations.

	Regional Municipality	SN6	SN5	SN4	SN5/SN6	SN4/SN6
2	Improvement District 23	346	395	393	1.14	1.14
3	Improvement District 22	360	415	410	1.15	1.14
4	Improvement District 18	367	410	402	1.12	1.09
5	Improvement District 17	365	418	410	1.15	1.12
6	Improvement District 21	368	419	411	1.14	1.12
7	Improvement District 20	367	416	405	1.13	1.1
8	Fairview	370	420	411	1.13	1.11
9	Peace	367	424	411	1.15	1.12
10	Spirit River	371	419	411	1.13	1.11
11	Improvement District 19	366	417	409	1.14	1.12
12	Smoky River	368	421	411	1.14	1.12
13	County 1 Grande Prairie	367	426	411	1.16	1.12
14	Improvement District 16	356	418	405	1.17	1.14
15	Improvement District 15	361	417	405	1.15	1.12
16	County 12 Athabasca	375	415	402	1.11	1.07
17	County 11 Barrhead	377	423	408	1.12	1.08
18	Westlock	382	425	411	1.11	1.08
19	County 7 Thorhild	384	423	410	1.1	1.07
20	County 13 Smoky Lake	382	422	414	1.11	1.08
21	County 19 St. Paul	377	422	416	1.12	1.1
22	Bonnyville	372	417	410	1.12	1.1
23	County 21Two Hills	379	421	422	1.11	1.11
24	County 24 Vermilion River	379	426	427	1.12	1.13
25	County 27 Minburn	384	429	429	1.12	1.12
26	County 9 Beaver	390	436	433	1.12	1.11
27	County 30 Lamont	396	439	436	1.11	1.1
28	Improvement District 13	395	438	433	1.11	1.1
29	County 20 Strathcona	395	439	430	1.11	1.09
30	Sturgeon	392	436	425	1.11	1.08
31	County 28 Lac Ste. Anne	379	423	409	1.11	1.08
32	County 31 Parkland	384	429	413	1.12	1.08
33	Improvement District 14	345	415	403	1.2	1.17
36	Clearwater	306	411	397	1.34	1.3
37	Brazeau	369	419	407	1.14	1.1
38	County 25 Leduc	390	436	421	1.12	1.08
39	County 10 Wetaskiwin	386	434	422	1.12	1.09
40	County 22 Camrose	392	441	433	1.12	1.11
41	County 3 Ponoka	386	441	424	1.14	1.1
42	County 29 Flagstaff	390	439	438	1.13	1.12
43	Wainwright	382	430	430	1.13	1.13
44	Provost	375	421	418	1.12	1.12
45	Special Area 4	370	419	415	1.13	1.12
46	Special Area 3	359	410	411	1.14	1.14
47	County 18 Paintearth	383	434	427	1.13	1.11
48	County 16 Stettler	386	439	430	1.14	1.11
49	County 14 Lacombe	384	444	423	1.16	1.1
51	County 17 Mountain View	365	435	416	1.19	1.14
52	Kneehill	381	431	423	1.13	1.11
53	Starland	382	432	432	1.13	1.13
54	Special Area 2	364	411	412	1.13	1.13
55	Acadia Valley	348	399	401	1.14	1.15
57	County 16 Wheatland	378	427	420	1.13	1.11
58	Rocky View	360	439	419	1.22	1.16
59	Bighorn	320	423	409	1.32	1.28
60	Improvement District 8	322	423	408	1.32	1.27
61	Improvement District 5	269	412	398	1.53	1.48
62	Foothill	352	436	418	1.24	1.19
63	County 2 Vulcan	379	424	421	1.12	1.11

Appendix C-VI.3b (Continued)

	Regional Municipality	SN6	SN5	SN4	SN5/SN6	SN4/SN6
64	County 4 Newell	367	408	411	1.11	1.12
65	Cypress	358	412	416	1.15	1.16
66	Suffield	352	401	408	1.14	1.16
67	County 8 Forty Mile	368	419	422	1.14	1.15
68	County 5 Warner	380	431	424	1.14	1.12
69	Taber	377	412	414	1.09	1.1
70	County 26 Lethbridge	382	422	418	1.11	1.09
71	Cardston	381	438	418	1.15	1.1
72	Willow Creek	372	432	417	1.16	1.12
73	Pincher Creek	369	435	414	1.18	1.12
75	Improvement District 6	345	429	411	1.24	1.19
76	Cold Lake Air Weapons Range	372	414	404	1.11	1.09
77	CFB Wainwright	383	430	428	1.12	1.12

Appendix C-VI.3c: Irrigated corn yields (g/m^2) averaged by Alberta Regional Municipalities for historical (1x; SN6) and doubled (2x; SN4 and SN5) atmospheric CO_2 concentrations. 0 represents areas without sufficient heat for corn to growth under current climate.

	Regional Municipality	SN6	SN5	SN4	SN5/SN6	SN4/SN6
4	Improvement District 18	0	803	830	0	0
5	Improvement District 17	0	817	835	0	0
7	Improvement District 20	0	758	756	0	0
10	Spirit River	0	754	752	0	0
11	Improvement District 19	0	761	760	0	0
13	County 1 Grande Prairie	0	757	755	0	0
14	Improvement District 16	0	787	792	0	0
15	Improvement District 15	0	835	850	0	0
16	County 12 Athabasca	0	811	843	0	0
17	County 11 Barrhead	0	822	841	0	0
18	Westlock	0	822	851	0	0
19	County 7 Thorhild	0	802	840	0	0
20	County 13 Smoky Lake	0	780	813	0	0
21	County 19 St. Paul	0	770	798	0	0
23	County 21 Two Hills	0	750	780	0	0
24	County 24 Vermilion River	0	758	783	0	0
25	County 27 Minburn	0	755	781	0	0
26	County 9 Beaver	0	764	790	0	0
27	County 30 Lamont	0	776	813	0	0
28	Improvement District 13	0	783	816	0	0
29	County 20 Strathcona	0	792	822	0	0
30	Sturgeon	0	803	835	0	0
31	County 28 Lac Ste. Anne	0	832	851	0	0
32	County 31 Parkland	0	826	848	0	0
33	Improvement District 14	0	813	828	0	0
36	Clearwater	0	815	836	0	0
37	Brazeau	0	818	840	0	0
38	County 25 Leduc	0	814	839	0	0
39	County 10 Wetaskiwin	0	810	837	0	0
40	County 22 Camrose	0	771	798	0	0
41	County 3 Ponoka	0	804	829	0	0
42	County 29 Flagstaff	0	751	778	0	0
43	Wainwright	0	753	772	0	0
44	Provost	0	739	758	0	0
45	Special Area 4	0	726	742	0	0
46	Special Area 3	662	692	707	1.05	1.07
47	County 18 Paintearth	0	742	763	0	0
48	County 16 Stettler	0	749	769	0	0
49	County 14 Lacombe	0	787	809	0	0
51	County 17 Mountain View	0	785	801	0	0
52	Kneehill	678	745	760	1.1	1.12
53	Starland	676	731	744	1.08	1.1
54	Special Area 2	664	697	711	1.05	1.07
55	Acadia Valley	654	657	676	1	1.03
57	County 16 Wheatland	684	734	752	1.07	1.1
58	Rocky View	0	788	802	0	0
59	Bighorn	0	772	791	0	0
60	Improvement District 8	0	782	800	0	0
61	Improvement District 5	0	792	805	0	0
62	Foothill	0	801	812	0	0
63	County 2 Vulcan	687	728	743	1.06	1.08
64	County 4 Newell	678	697	713	1.03	1.05
65	Cypress	661	680	691	1.03	1.04
66	Suffield	656	665	677	1.01	1.03
67	County 8 Forty Mile	668	692	705	1.04	1.06
68	County 5 Warner	676	732	744	1.08	1.1
69	Taber	682	702	715	1.03	1.05
70	County 26 Lethbridge	691	729	738	1.06	1.07

Appendix C-VI.3c (Continued)

	Regional Municipality	SN6	SN5	SN4	SN5/SN6	SN4/SN6
71	Cardston	683	779	786	1.14	1.15
72	Willow Creek	0	782	789	0	0
73	Pincher Creek	0	810	817	0	0
75	Improvement District 6	0	804	812	0	0
77	CFB Wainwright	0	748	768	0	0

APPENDIX D

Model outputs averaged by Soil Landscapes of Canada

Appendix D-VI.1a: Dryland canola yields (g/m^2) averaged by Alberta Soil Landscape polygones for historical (1x; SN6) and doubled (2x; SN4 and SN5) atmospheric CO_2 concentrations.

Poly.#	Soil	SN6	SN5	SN4	SN5/SN6	SN4/SN6
2	FAL	211	281	260	1.33	1.24
3	DON	218	286	268	1.31	1.23
4	HZM	223	284	267	1.27	1.2
5	DON	228	284	268	1.24	1.18
6	ESH	225	294	277	1.31	1.23
7	COS	212	282	264	1.33	1.24
9	BBN	212	282	273	1.33	1.29
10	BBN	223	283	275	1.27	1.23
11	ESH	230	283	273	1.23	1.19
13	HZM	201	280	271	1.39	1.35
14	COS	206	282	277	1.36	1.34
15	ABT	202	280	274	1.39	1.36
19	HZM	203	280	274	1.38	1.35
20	LAD	211	279	271	1.32	1.28
22	COS	198	278	267	1.4	1.34
27	DON	183	270	268	1.47	1.46
28	HZM	212	282	266	1.33	1.25
32	HRT	211	276	265	1.31	1.26
33	HRT	210	277	266	1.31	1.26
36	COS	207	274	266	1.33	1.29
47	DON	220	279	267	1.27	1.21
48	DON	221	279	268	1.26	1.22
49	TAG	218	278	268	1.27	1.23
51	SAD	228	282	273	1.24	1.2
52	VVW	217	279	269	1.28	1.24
53	TAG	210	277	267	1.32	1.27
54	ESH	233	282	273	1.21	1.17
56	ZBR	220	282	266	1.28	1.21
59	FAL	236	289	267	1.23	1.13
60	BBN	244	298	271	1.22	1.11
61	RYF	233	283	271	1.21	1.16
62	DVS	229	276	255	1.2	1.11
64	JUH	234	284	262	1.21	1.12
68	HRT	230	279	260	1.21	1.13
70	JUH	235	280	266	1.19	1.13
71	BBN	234	283	270	1.21	1.16
72	BLY	233	282	270	1.21	1.16
73	RYF	233	283	272	1.22	1.17
74	JUH	240	283	273	1.18	1.13
75	DIG	228	292	284	1.28	1.24
76	JUH	235	283	266	1.2	1.13
77	LAD	234	287	277	1.23	1.19
78	ABT	234	285	271	1.22	1.16
80	BWY	231	288	263	1.25	1.14
81	HZM	230	289	275	1.25	1.19
83	BUD	231	290	271	1.26	1.17
84	HZM	231	290	269	1.25	1.16
87	NPA	223	306	288	1.37	1.29
88	FAL	223	307	290	1.37	1.3
89	JUH	214	284	266	1.33	1.24
91	HZM	220	293	282	1.33	1.28
93	DON	221	313	292	1.42	1.32
94	HRT	228	290	283	1.27	1.24
97	FAL	239	295	273	1.23	1.14
98	HZM	233	293	271	1.26	1.16
99	CUL	238	300	288	1.26	1.21
101	FAL	233	290	267	1.24	1.14
102	WHW	233	293	266	1.25	1.14
103	ABT	233	287	276	1.23	1.19
104	HZM	235	291	277	1.24	1.18
105	CTE	242	303	279	1.25	1.15
107	ALC	227	292	279	1.29	1.23
108	HZM	233	286	279	1.23	1.2
109	PRV	235	292	276	1.24	1.17
110	CTE	246	310	280	1.26	1.14
112	ALC	239	295	280	1.24	1.17
130	DVS	200	243	234	1.22	1.17
132	CTE	186	247	238	1.32	1.28
133	BBN	228	291	269	1.28	1.18
135	DVS	233	291	268	1.25	1.15
144	BBN	181	270	256	1.49	1.41
170	HUB	174	288	253	1.65	1.45
171	HUB	197	295	260	1.49	1.32
172	KTH	213	291	271	1.36	1.27
173	CUL	214	292	272	1.36	1.27
176	HRT	240	280	274	1.16	1.14
177	HRT	229	300	271	1.31	1.19
178	HPE	248	293	284	1.18	1.15
180	KNZ	235	291	278	1.24	1.18
181	COS	226	286	274	1.26	1.21
182	ATO	250	297	288	1.18	1.15
185	UCS	253	295	287	1.17	1.13
189	CUL	241	282	274	1.17	1.14
192	COA	231	289	273	1.25	1.18
193	MLA	233	294	272	1.26	1.16
194	MLA	252	291	282	1.15	1.12
196	LNN	265	303	298	1.14	1.12
197	COA	263	296	286	1.13	1.09
198	COA	250	289	276	1.16	1.1
201	HRT	211	294	272	1.39	1.29
211	ZOR	226	276	270	1.22	1.19
212	ABC	235	269	265	1.14	1.13
215	ABC	231	273	271	1.18	1.17
218	KNZ	237	260	266	1.1	1.12
221	EGL	243	257	247	1.06	1.02
224	ABC	242	256	248	1.06	1.03
227	TNW	239	255	261	1.07	1.09
231	ABC	242	258	265	1.07	1.1
232	MLA	232	246	255	1.06	1.1
233	KNZ	233	249	254	1.07	1.09
236	ABC	235	259	255	1.1	1.09
240	KNZ	239	257	261	1.08	1.09
246	GDI	240	266	264	1.11	1.1
248	GDI	249	277	275	1.11	1.1
250	ABC	247	279	275	1.13	1.11
252	UCS	248	289	284	1.16	1.14
253	COD	256	291	288	1.13	1.12
254	PIB	265	299	295	1.13	1.11
258	POK	271	290	294	1.07	1.08
259	RDW	265	289	289	1.09	1.09
261	NIT	266	285	288	1.07	1.08
264	COA	263	281	284	1.07	1.08
268	KNZ	252	269	274	1.07	1.09
271	FLU	262	280	285	1.07	1.09
275	RDW	250	272	276	1.09	1.11
279	ABC	248	279	277	1.13	1.12

Appendix D-VI.1a (Continued).

Poly.#	Soil	SN6	SN5	SN4	SN5/SN6	SN4/SN6
290	ABC	251	277	274	1.1	1.09
291	LCY	261	280	276	1.07	1.06
292	TMN	263	277	277	1.06	1.05
296	NIT	229	226	255	0.99	1.11
297	GOG	253	269	272	1.06	1.07
301	SDN	234	244	262	1.04	1.12
302	LCY	232	232	257	1	1.11
306	LCY	245	279	274	1.14	1.12
310	FRY	239	256	265	1.07	1.11
311	FRY	244	268	272	1.1	1.11
312	FRY	235	253	264	1.08	1.12
315	NTW	249	263	272	1.06	1.09
316	LCY	253	267	272	1.05	1.07
317	LCY	254	265	271	1.04	1.06
320	FRY	258	264	269	1.03	1.04
322	LCY	267	287	271	1.07	1.01
323	LCY	266	285	272	1.07	1.02
325	LCY	259	275	271	1.06	1.05
326	LCY	240	248	263	1.03	1.1
334	LCY	250	276	274	1.1	1.1
335	FRY	262	286	272	1.09	1.04
337	MGS	263	291	288	1.11	1.09
339	LFN	263	293	289	1.11	1.1
341	MGS	262	289	280	1.1	1.07
342	LFN	261	292	282	1.12	1.08
343	FRY	261	295	284	1.13	1.09
344	BSU	263	292	288	1.11	1.09
345	SDN	264	292	289	1.1	1.1
346	PHS	257	285	281	1.11	1.09
347	SDN	246	260	270	1.06	1.1
348	SDN	244	262	269	1.07	1.1
350	LFN	252	258	267	1.03	1.06
351	LFN	261	281	283	1.08	1.08
352	RDW	266	285	286	1.07	1.07
354	BVH	263	295	297	1.12	1.13
356	EOR	264	288	287	1.09	1.09
357	EOR	264	291	292	1.1	1.11
359	RED	263	287	294	1.09	1.12
360	EOR	264	290	295	1.1	1.11
362	EOR	267	288	291	1.08	1.09
363	EOR	265	286	290	1.08	1.09
364	EOR	259	290	294	1.12	1.13
365	HND	255	276	286	1.08	1.12
366	DCY	255	270	283	1.06	1.11
367	HND	257	273	285	1.06	1.11
370	HND	231	221	253	0.96	1.09
371	WWT	247	259	277	1.05	1.12
372	EOR	256	273	287	1.07	1.12
374	EOR	260	281	286	1.08	1.1
375	WWT	255	275	282	1.08	1.11
376	HND	251	269	281	1.07	1.12
378	HND	249	266	279	1.07	1.12
392	AGS	246	258	271	1.05	1.1
393	LIZ	267	286	290	1.07	1.08
396	AGS	271	290	292	1.07	1.08
401	MGS	276	288	298	1.04	1.08
403	CMO	266	287	292	1.08	1.09
404	AGS	269	289	292	1.07	1.08
405	CMO	256	272	280	1.06	1.09
408	AGS	258	278	285	1.08	1.11
409	AGS	260	288	289	1.11	1.11
410	UCS	265	285	290	1.08	1.1
411	COA	268	290	290	1.08	1.08
412	CMO	258	282	285	1.09	1.1
416	WKN	279	290	299	1.04	1.07
418	MMO	270	293	291	1.08	1.08
420	TBY	270	295	289	1.1	1.07
421	HND	227	229	267	1.01	1.18
422	HCH	219	223	264	1.01	1.2
423	LET	219	230	268	1.05	1.22
425	HND	202	209	273	1.03	1.35
426	MMO	273	293	292	1.08	1.07
428	HND	178	185	265	1.04	1.49
429	FLU	268	292	289	1.09	1.08
430	MCO	264	291	289	1.1	1.1
431	AGS	262	293	290	1.12	1.11
432	KVG	265	293	287	1.11	1.08
433	POK	267	295	288	1.1	1.08
435	BTN	263	293	279	1.12	1.06
437	POK	262	294	285	1.12	1.09
439	COA	265	287	290	1.08	1.09
440	COA	272	296	289	1.09	1.06
441	MMO	274	294	293	1.07	1.07
442	WTB	275	296	292	1.08	1.06
443	HND	221	229	274	1.03	1.24
444	MET	241	256	280	1.06	1.16
449	KUR	167	176	258	1.05	1.54
451	MET	137	148	255	1.08	1.86
452	LET	146	157	255	1.07	1.74
453	CHN	132	143	255	1.09	1.93
457	MAB	119	131	245	1.1	2.05
458	MAB	112	123	229	1.1	2.04
460	WDN	114	125	235	1.1	2.06
461	BVL	120	131	249	1.1	2.07
463	HND	122	134	257	1.1	2.1
466	HND	138	149	255	1.08	1.84
467	WWT	154	164	257	1.07	1.67
471	HUK	138	149	256	1.07	1.85
472	MAB	111	124	237	1.12	2.13
473	HND	127	138	255	1.09	2.01
474	MAB	117	129	244	1.1	2.09
475	BVL	116	129	250	1.11	2.15
476	MAB	114	128	251	1.13	2.2
478	CCL	123	135	256	1.1	2.09
480	HUK	144	151	258	1.05	1.79
481	YTW	147	152	258	1.04	1.76
484	WWT	179	186	266	1.04	1.48
486	YTW	153	160	261	1.05	1.71
487	HUK	116	130	237	1.12	2.05
489	HUK	134	144	253	1.08	1.88
494	LHD	214	222	271	1.04	1.27
496	MET	144	153	263	1.06	1.82
499	CVD	105	120	167	1.14	1.6
508	AGS	259	292	290	1.13	1.12
509	PHS	259	294	284	1.13	1.09
510	AGS	257	285	285	1.11	1.11
512	BVH	258	292	291	1.13	1.13
513	AGS	258	290	288	1.12	1.12
514	PHS	253	296	293	1.17	1.16
515	BVH	247	293	293	1.19	1.18

Appendix D-VI.1a (Continued).

Poly.#	Soil	SN6	SN5	SN4	SN5/SN6	SN4/SN6
516	BVH	252	298	294	1.18	1.16
517	FLU	253	300	297	1.18	1.17
518	MGS	256	298	291	1.16	1.13
519	NVR	257	295	291	1.15	1.13
520	AGS	258	295	290	1.15	1.12
521	POK	258	296	286	1.15	1.11
523	PED	254	299	291	1.18	1.15
524	FLU	259	297	286	1.15	1.11
531	GDB	257	280	285	1.09	1.11
532	HKR	226	238	275	1.05	1.22
533	HND	203	213	274	1.05	1.35
534	MET	211	223	278	1.06	1.32
536	HND	229	246	283	1.08	1.24
537	BVH	249	279	287	1.12	1.15
538	HND	235	258	287	1.1	1.23
539	PHS	254	282	286	1.11	1.13
540	KLM	257	278	284	1.08	1.1
543	EOR	239	269	291	1.13	1.22
545	IRM	244	282	283	1.16	1.2
547	DEL	241	281	294	1.16	1.22
548	BVH	246	292	293	1.19	1.19
549	FLU	251	297	292	1.18	1.17
551	FLU	248	297	294	1.19	1.18
553	ATL	244	296	297	1.22	1.22
554	ATL	218	311	299	1.43	1.38
555	CYG	261	304	295	1.16	1.13
558	DEL	225	321	304	1.42	1.35
559	ATL	153	288	283	1.88	1.84
561	ATL	177	291	287	1.64	1.62
562	BGH	192	301	292	1.57	1.52
563	BSK	236	301	299	1.28	1.27
564	LET	167	222	276	1.32	1.65
565	DEL	229	320	305	1.4	1.34
566	DEL	208	302	302	1.45	1.45
567	BSK	223	287	296	1.29	1.33
568	DEL	236	269	294	1.14	1.25
569	IRM	231	278	295	1.2	1.27
570	HAN	227	261	291	1.15	1.28
571	HAN	201	213	278	1.06	1.38
572	DVG	157	277	284	1.77	1.81
574	LET	219	261	288	1.19	1.32
575	WWT	197	247	287	1.25	1.46
576	DMH	201	229	285	1.14	1.42
577	BZR	166	268	279	1.61	1.67
578	HAN	175	196	282	1.12	1.61
579	LET	193	236	284	1.22	1.47
581	HKR	169	177	268	1.05	1.59
582	HAN	183	196	277	1.07	1.51
583	HAN	178	190	273	1.06	1.53
584	DMH	210	227	284	1.08	1.35
589	HAN	173	186	276	1.08	1.59
590	CHN	103	113	209	1.1	2.03
591	BVL	107	119	225	1.12	2.11
592	FMT	107	120	229	1.13	2.14
593	CVD	107	121	231	1.13	2.16
595	ATP	101	112	222	1.11	2.2
596	FMT	114	132	233	1.15	2.03
598	FMT	116	134	233	1.16	2.01
599	MAB	108	124	225	1.15	2.08
600	CVD	113	131	222	1.16	1.97
601	MAB	111	126	235	1.14	2.12
602	MAB	109	125	229	1.15	2.1
603	MAB	117	134	232	1.14	1.98
605	HDY	119	135	238	1.13	2
606	CVD	113	129	205	1.14	1.81
607	CVD	123	139	219	1.13	1.77
608	MCT	134	151	251	1.13	1.87
609	TIY	125	141	242	1.13	1.93
610	BVL	131	147	259	1.13	1.98
611	HUK	133	150	260	1.13	1.95
613	CCL	142	160	277	1.12	1.94
615	CVD	136	155	267	1.15	1.97
616	CHN	127	147	253	1.16	1.99
617	FMT	119	141	233	1.18	1.95
618	CHN	118	141	228	1.19	1.92
619	FMT	122	146	236	1.2	1.94
620	MAB	128	164	255	1.28	1.99
621	TTH	141	187	259	1.32	1.83
622	TTH	142	190	266	1.34	1.87
623	ZRB	143	195	272	1.36	1.9
624	THA	158	223	279	1.4	1.76
626	SIL	113	149	271	1.31	2.39
627	MAB	117	152	268	1.3	2.28
628	BVL	121	154	267	1.28	2.21
629	SIL	119	153	267	1.28	2.24
631	MAB	122	151	261	1.23	2.13
632	MAB	126	154	274	1.21	2.17
633	MAB	134	166	276	1.24	2.06
634	MAB	124	154	269	1.25	2.18
635	MAB	126	156	272	1.23	2.14
637	MSN	135	168	276	1.25	2.05
638	ZRB	127	156	273	1.23	2.14
639	PUR	146	203	280	1.39	1.91
641	MAB	137	164	273	1.2	1.99
642	MAB	135	156	270	1.16	2
643	CHN	144	165	274	1.15	1.9
645	DLB	163	235	286	1.44	1.76
648	CFD	131	148	261	1.13	1.99
649	BVL	143	159	276	1.12	1.93
650	MAB	141	157	277	1.12	1.97
651	RDM	152	181	286	1.19	1.88
653	LET	176	233	280	1.33	1.59
654	PUY	149	170	279	1.14	1.87
655	DEL	185	275	288	1.48	1.56
656	PUY	171	246	278	1.43	1.62
657	LET	158	217	273	1.37	1.73
658	CMY	156	211	263	1.36	1.69
659	DEL	180	283	285	1.57	1.58
660	CVD	139	157	267	1.13	1.92
661	RDM	147	172	281	1.17	1.91
663	LET	156	205	271	1.31	1.73
664	RDM	159	204	276	1.28	1.74
666	PUR	147	204	280	1.39	1.9
667	LET	158	209	281	1.32	1.78
669	LOB	185	289	285	1.56	1.54
671	PHS	228	296	293	1.3	1.28
672	PED	241	299	293	1.24	1.22
673	MMO	240	300	290	1.25	1.21
675	BTN	242	297	288	1.23	1.19
676	CYG	252	298	288	1.18	1.14

Appendix D-VI.1a (Continued).

Poly.#	Soil	SN6	SN5	SN4	SN5/SN6	SN4/SN6
677	BEN	246	300	291	1.22	1.18
680	PNC	165	285	271	1.73	1.65
681	CYG	204	293	283	1.43	1.39
682	BEN	202	291	281	1.44	1.39
683	HUB	236	297	286	1.26	1.21
684	CAR	177	286	274	1.61	1.54
686	LOB	175	287	279	1.64	1.6
689	CAR	171	273	267	1.59	1.56
690	RMY	222	293	285	1.32	1.28
691	HUB	206	288	282	1.39	1.36
692	BTN	226	293	286	1.3	1.27
693	RMY	251	297	287	1.18	1.14
694	HUB	245	296	284	1.21	1.16
695	BTN	253	295	279	1.17	1.1
696	BTN	248	298	285	1.2	1.15
698	MYW	232	299	285	1.29	1.23
699	HUB	245	295	283	1.2	1.15
702	CVL	269	296	289	1.1	1.07
703	HGV	254	293	282	1.15	1.11
705	MCO	241	288	278	1.19	1.15
708	MLA	240	290	274	1.21	1.14
709	COA	251	292	272	1.16	1.08
710	COA	262	295	284	1.12	1.08
711	COA	256	292	276	1.14	1.08
715	KVG	264	295	283	1.12	1.07

Appendix D-VI.1b: Dryland spring wheat yields (g/m^2) averaged by Alberta Soil Landscape polygones for historical (1x; SN6) and doubled (2x; SN4 and SN5) atmospheric CO_2 concentrations.

Poly.#	Soil	SN6	SN5	SN4	SN5/SN6	SN4/SN6
2	FAL	120	146	146	1.21	1.22
3	DON	124	152	152	1.22	1.22
4	HZM	126	154	154	1.22	1.22
5	DON	128	156	156	1.22	1.22
6	ESH	127	156	157	1.23	1.23
7	COS	123	150	150	1.22	1.22
9	BBN	132	165	164	1.25	1.25
10	BBN	136	171	170	1.25	1.25
11	ESH	136	169	169	1.24	1.24
13	HZM	131	164	164	1.25	1.25
14	COS	135	171	171	1.27	1.26
15	ABT	135	171	170	1.26	1.26
19	HZM	135	171	170	1.26	1.26
20	LAD	135	169	168	1.25	1.24
22	COS	133	166	164	1.25	1.24
27	DON	127	158	156	1.25	1.23
28	HZM	125	154	153	1.23	1.23
32	HRT	135	168	166	1.25	1.23
33	HRT	135	168	166	1.25	1.23
36	COS	133	165	163	1.24	1.23
47	DON	132	162	162	1.23	1.23
48	DON	134	166	165	1.24	1.23
49	TAG	135	168	166	1.24	1.23
51	SAD	137	172	170	1.25	1.24
52	VVW	135	169	167	1.25	1.24
53	TAG	134	168	166	1.25	1.23
54	ESH	138	171	170	1.24	1.23
56	ZBR	131	161	162	1.23	1.23
59	FAL	130	158	160	1.21	1.23
60	BBN	131	158	161	1.21	1.23
61	RYF	136	168	167	1.24	1.23
62	DVS	127	152	153	1.2	1.2
64	JUH	130	156	158	1.21	1.22
68	HRT	130	157	157	1.21	1.21
70	JUH	133	163	164	1.22	1.22
71	BBN	136	167	167	1.23	1.23
72	BLY	135	167	167	1.24	1.23
73	RYF	134	166	166	1.24	1.23
74	JUH	137	170	170	1.24	1.24
75	DIG	133	166	166	1.25	1.25
76	JUH	133	163	164	1.22	1.23
77	LAD	135	167	168	1.24	1.25
78	ABT	134	165	165	1.23	1.24
80	BWY	132	162	164	1.23	1.24
81	HZM	133	166	167	1.24	1.25
83	BUD	133	165	167	1.24	1.25
84	HZM	133	165	167	1.24	1.25
87	NPA	128	159	161	1.24	1.25
88	FAL	129	160	162	1.24	1.25
89	JUH	122	150	150	1.22	1.22
91	HZM	127	158	159	1.24	1.25
93	DON	127	157	158	1.24	1.25
94	HRT	133	167	167	1.25	1.26
97	FAL	133	162	165	1.21	1.24
98	HZM	136	167	170	1.23	1.25
99	CUL	140	173	177	1.23	1.26
101	FAL	133	163	165	1.22	1.24
102	WHW	134	165	168	1.23	1.25

Poly.#	Soil	SN6	SN5	SN4	SN5/SN6	SN4/SN6
103	ABT	135	168	170	1.24	1.25
104	HZM	137	170	172	1.24	1.26
105	CTE	141	174	178	1.24	1.26
107	ALC	132	164	165	1.24	1.25
108	HZM	137	170	172	1.24	1.26
109	PRV	138	171	173	1.24	1.26
110	CTE	143	178	182	1.24	1.27
112	ALC	140	173	176	1.24	1.26
130	DVS	115	134	138	1.16	1.2
132	CTE	120	143	145	1.19	1.21
133	BBN	131	159	162	1.22	1.24
135	DVS	130	158	161	1.21	1.23
144	BBN	118	145	145	1.23	1.24
170	HUB	118	146	147	1.24	1.25
171	HUB	121	147	148	1.22	1.23
172	KTH	124	148	150	1.2	1.21
173	CUL	124	149	150	1.19	1.21
176	HRT	126	148	151	1.18	1.19
177	HRT	125	150	152	1.2	1.21
178	HPE	131	156	160	1.19	1.22
180	KNZ	127	151	154	1.19	1.21
181	COS	124	147	150	1.18	1.2
182	ATO	132	158	162	1.2	1.23
185	UCS	132	158	162	1.2	1.23
189	CUL	126	149	152	1.17	1.2
192	COA	126	149	151	1.18	1.2
193	MLA	126	150	152	1.19	1.2
194	MLA	131	156	159	1.19	1.21
196	LNN	137	165	170	1.21	1.24
197	COA	135	162	165	1.2	1.22
198	COA	129	153	155	1.18	1.2
201	HRT	124	149	150	1.19	1.2
211	ZOR	123	145	147	1.17	1.19
212	ABC	123	144	146	1.17	1.19
215	ABC	124	146	148	1.18	1.2
218	KNZ	126	148	152	1.17	1.2
221	EGL	123	144	145	1.16	1.18
224	ABC	124	144	146	1.16	1.18
227	TNW	125	146	150	1.17	1.2
231	ABC	127	150	154	1.18	1.21
232	MLA	124	144	148	1.16	1.19
233	KNZ	124	144	147	1.16	1.19
236	ABC	124	145	148	1.17	1.19
240	KNZ	126	148	151	1.17	1.2
246	GDI	125	146	150	1.17	1.2
248	GDI	125	147	152	1.18	1.21
250	ABC	129	155	159	1.2	1.23
252	UCS	131	156	160	1.19	1.22
253	COD	133	160	165	1.2	1.24
254	PIB	137	166	171	1.21	1.25
258	POK	145	182	186	1.26	1.28
259	RDW	137	169	173	1.23	1.26
261	NIT	136	168	173	1.23	1.26
264	COA	132	160	165	1.21	1.25
268	KNZ	130	155	160	1.2	1.23
271	FLU	141	178	182	1.26	1.28
275	RDW	141	177	181	1.26	1.29
279	ABC	134	166	170	1.23	1.26

Appendix D-VI.1b (Continued).

Poly.#	Soil	SN6	SN5	SN4	SN5/SN6	SN4/SN6
290	ABC	124	144	148	1.17	1.2
291	LCY	124	145	149	1.17	1.2
292	TMN	124	145	149	1.16	1.2
296	NIT	125	145	150	1.16	1.2
297	GOG	126	147	152	1.17	1.21
301	SDN	128	151	156	1.18	1.22
302	LCY	127	150	155	1.18	1.22
306	LCY	130	158	163	1.21	1.25
310	FRY	138	171	177	1.24	1.28
311	FRY	140	175	180	1.25	1.29
312	FRY	140	173	180	1.24	1.29
315	NTW	126	147	151	1.17	1.2
316	LCY	127	150	154	1.18	1.21
317	LCY	127	149	154	1.18	1.21
320	FRY	129	153	158	1.19	1.23
322	LCY	132	161	166	1.22	1.26
323	LCY	132	162	167	1.22	1.26
325	LCY	132	161	165	1.22	1.25
326	LCY	130	155	160	1.2	1.24
334	LCY	139	174	180	1.25	1.29
335	FRY	134	166	171	1.24	1.27
337	MGS	144	183	186	1.27	1.29
339	LFN	145	185	188	1.28	1.3
341	MGS	138	173	178	1.25	1.28
342	LFN	139	174	179	1.25	1.29
343	FRY	139	175	180	1.26	1.29
344	BSU	142	179	184	1.26	1.29
345	SDN	143	181	185	1.27	1.3
346	PHS	141	178	183	1.26	1.29
347	SDN	145	184	189	1.26	1.3
348	SDN	143	180	186	1.26	1.3
350	LFN	149	190	193	1.27	1.29
351	LFN	146	185	189	1.27	1.3
352	RDW	146	187	190	1.28	1.29
354	BVH	149	193	195	1.29	1.3
356	EOR	144	186	191	1.29	1.33
357	EOR	145	186	191	1.28	1.31
359	RED	144	185	191	1.29	1.33
360	EOR	144	185	190	1.28	1.32
362	EOR	144	184	189	1.28	1.31
363	EOR	143	183	188	1.28	1.31
364	EOR	150	194	199	1.29	1.33
365	HND	144	184	189	1.27	1.31
366	DCY	141	179	184	1.26	1.3
367	HND	141	179	185	1.27	1.31
370	HND	131	156	163	1.19	1.25
371	WWT	134	167	174	1.24	1.29
372	EOR	140	179	185	1.27	1.32
374	EOR	141	181	187	1.28	1.32
375	WWT	137	174	181	1.27	1.32
376	HND	132	165	173	1.24	1.3
378	HND	128	157	166	1.23	1.29
392	AGS	150	193	197	1.29	1.32
393	LIZ	157	209	210	1.33	1.34
396	AGS	154	202	203	1.31	1.31
401	MGS	153	199	202	1.3	1.32
403	CMO	160	214	214	1.34	1.34
404	AGS	162	220	219	1.36	1.35
405	CMO	155	204	206	1.32	1.33
408	AGS	155	204	204	1.31	1.31
409	AGS	159	208	207	1.31	1.3
410	UCS	156	206	206	1.32	1.32
411	COA	153	198	197	1.29	1.29
412	CMO	154	200	199	1.3	1.3
416	WKN	154	201	204	1.3	1.32
418	MMO	142	175	179	1.23	1.26
420	TBY	139	168	171	1.21	1.23
421	HND	132	161	170	1.22	1.29
422	HCH	128	154	163	1.2	1.27
423	LET	125	150	159	1.2	1.27
425	HND	126	154	167	1.22	1.32
426	MMO	149	190	191	1.27	1.28
428	HND	118	142	161	1.2	1.36
429	FLU	153	196	196	1.29	1.28
430	MCO	156	202	201	1.29	1.29
431	AGS	158	204	204	1.29	1.29
432	KVG	148	187	189	1.26	1.27
433	POK	145	181	183	1.25	1.26
435	BTN	140	172	175	1.23	1.25
437	POK	149	188	190	1.26	1.27
439	COA	155	203	203	1.31	1.31
440	COA	140	170	173	1.21	1.23
441	MMO	147	185	187	1.26	1.28
442	WTB	145	181	184	1.25	1.27
443	HND	131	162	172	1.23	1.31
444	MET	138	174	181	1.26	1.31
449	KUR	115	138	156	1.2	1.36
451	MET	107	129	158	1.21	1.48
452	LET	109	132	156	1.21	1.43
453	CHN	105	127	160	1.21	1.52
457	MAB	101	122	160	1.21	1.59
458	MAB	97	117	157	1.21	1.62
460	WDN	98	119	158	1.21	1.61
461	BVL	101	122	160	1.21	1.58
463	HND	103	125	164	1.21	1.58
466	HND	107	129	157	1.21	1.47
467	WWT	111	134	156	1.2	1.4
471	HUK	107	128	156	1.2	1.46
472	MAB	95	117	155	1.23	1.63
473	HND	103	124	158	1.2	1.53
474	MAB	98	120	157	1.22	1.59
475	BVL	98	119	155	1.22	1.58
476	MAB	95	118	153	1.24	1.6
478	CCL	101	121	155	1.2	1.53
480	HUK	108	126	153	1.17	1.42
481	YTW	109	126	153	1.16	1.4
484	WWT	119	144	162	1.21	1.36
486	YTW	112	133	157	1.19	1.41
487	HUK	96	120	150	1.25	1.56
489	HUK	106	129	156	1.22	1.47
494	LHD	128	159	169	1.24	1.32
496	MET	111	135	160	1.22	1.44
499	CVD	89	115	129	1.29	1.45
508	AGS	155	200	202	1.29	1.3
509	PHS	147	186	187	1.26	1.27
510	AGS	151	194	195	1.28	1.29
512	BVH	149	191	194	1.28	1.31
513	AGS	154	199	201	1.29	1.3
514	PHS	147	187	191	1.28	1.3
515	BVH	145	185	188	1.27	1.3
516	BVH	146	185	188	1.27	1.29
517	FLU	148	188	190	1.27	1.29

Appendix D-VI.1b (Continued).

Poly.#	Soil	SN6	SN5	SN4	SN5/SN6	SN4/SN6
518	MGS	146	185	187	1.26	1.28
519	NVR	158	203	204	1.29	1.3
520	AGS	152	195	196	1.28	1.29
521	POK	144	181	184	1.25	1.27
523	PED	143	180	182	1.26	1.28
524	FLU	143	178	180	1.25	1.26
531	GDB	143	183	188	1.28	1.31
532	HKR	131	163	173	1.24	1.31
533	HND	129	162	174	1.25	1.34
534	MET	135	172	181	1.27	1.34
536	HND	140	179	185	1.28	1.32
537	BVH	141	179	183	1.27	1.3
538	HND	142	182	187	1.28	1.31
539	PHS	141	179	183	1.26	1.29
540	KLM	139	175	180	1.26	1.29
543	EOR	145	185	189	1.28	1.3
545	IRM	145	185	189	1.27	1.3
547	DEL	144	184	187	1.28	1.3
548	BVH	143	183	186	1.28	1.3
549	FLU	144	183	186	1.27	1.29
551	FLU	142	181	183	1.27	1.29
553	ATL	142	182	184	1.28	1.29
554	ATL	140	186	188	1.33	1.33
555	CYG	143	181	183	1.26	1.28
558	DEL	145	193	194	1.33	1.34
559	ATL	123	173	173	1.4	1.4
561	ATL	127	173	173	1.36	1.36
562	BGH	134	183	184	1.37	1.38
563	BSK	141	183	184	1.29	1.3
564	LET	125	166	172	1.33	1.38
565	DEL	145	193	195	1.33	1.34
566	DEL	138	186	190	1.34	1.37
567	BSK	139	181	185	1.3	1.33
568	DEL	145	186	189	1.28	1.3
569	IRM	142	183	186	1.29	1.31
570	HAN	140	180	184	1.28	1.31
571	HAN	135	174	184	1.29	1.36
572	DVG	128	178	178	1.38	1.38
574	LET	135	173	178	1.28	1.32
575	WWT	127	164	172	1.29	1.36
576	DMH	132	171	179	1.29	1.36
577	BZR	130	176	177	1.36	1.36
578	HAN	128	169	180	1.32	1.41
579	LET	124	161	170	1.29	1.37
581	HKR	120	150	167	1.24	1.39
582	HAN	132	170	181	1.29	1.38
583	HAN	127	162	176	1.28	1.38
584	DMH	139	179	187	1.29	1.35
589	HAN	129	167	179	1.29	1.39
590	CHN	92	112	156	1.21	1.68
591	BVL	93	116	157	1.24	1.68
592	FMT	93	118	160	1.26	1.71
593	CVD	93	117	159	1.25	1.71
595	ATP	91	112	168	1.23	1.85
596	FMT	100	129	174	1.29	1.74
598	FMT	101	131	175	1.3	1.73
599	MAB	94	123	167	1.31	1.77
600	CVD	99	130	171	1.31	1.73
601	MAB	93	120	154	1.29	1.65
602	MAB	94	122	160	1.3	1.71

Poly.#	Soil	SN6	SN5	SN4	SN5/SN6	SN4/SN6
603	MAB	99	130	164	1.3	1.65
605	HDY	97	128	158	1.32	1.62
606	CVD	93	123	143	1.32	1.53
607	CVD	99	130	148	1.32	1.49
608	MCT	104	139	158	1.35	1.53
609	TIY	98	132	153	1.35	1.57
610	BVL	103	135	160	1.32	1.55
611	HUK	104	140	162	1.35	1.56
613	CCL	108	148	168	1.37	1.55
615	CVD	108	142	166	1.31	1.53
616	CHN	107	141	171	1.31	1.59
617	FMT	106	140	176	1.32	1.66
618	CHN	104	138	176	1.32	1.69
619	FMT	106	141	177	1.33	1.66
620	MAB	106	144	175	1.35	1.64
621	TTH	109	147	173	1.34	1.58
622	TTH	109	148	172	1.35	1.58
623	ZRB	108	148	171	1.36	1.58
624	THA	112	151	169	1.35	1.51
626	SIL	100	141	175	1.42	1.75
627	MAB	102	143	175	1.4	1.71
628	BVL	105	145	175	1.38	1.68
629	SIL	104	144	175	1.39	1.69
631	MAB	108	148	178	1.37	1.64
632	MAB	110	151	178	1.36	1.61
633	MAB	113	153	176	1.35	1.56
634	MAB	108	149	178	1.38	1.64
635	MAB	110	151	178	1.37	1.62
637	MSN	113	153	176	1.35	1.55
638	ZRB	110	151	178	1.37	1.61
639	PUR	119	162	175	1.36	1.47
641	MAB	113	151	174	1.34	1.55
642	MAB	112	148	173	1.32	1.55
643	CHN	112	149	170	1.33	1.52
645	DLB	126	172	177	1.36	1.4
648	CFD	102	131	155	1.28	1.51
649	BVL	112	145	175	1.3	1.56
650	MAB	110	146	173	1.33	1.57
651	RDM	115	156	175	1.36	1.52
653	LET	123	161	171	1.31	1.39
654	PUY	111	152	170	1.36	1.52
655	DEL	130	176	180	1.35	1.39
656	PUY	125	166	173	1.32	1.38
657	LET	121	161	171	1.32	1.4
658	CMY	120	155	185	1.29	1.37
659	DEL	132	181	183	1.37	1.39
660	CVD	106	144	164	1.36	1.55
661	RDM	113	151	173	1.34	1.53
663	LET	119	156	169	1.31	1.41
664	RDM	118	156	170	1.32	1.44
666	PUR	119	162	175	1.36	1.46
667	LET	121	164	174	1.35	1.43
669	LOB	126	167	168	1.33	1.34
671	PHS	137	176	178	1.29	1.3
672	PED	139	178	180	1.28	1.29
673	MMO	138	175	177	1.27	1.29
675	BTN	137	173	175	1.26	1.27
676	CYG	141	177	179	1.26	1.27
677	BEN	139	176	178	1.27	1.28
680	PNC	117	153	155	1.31	1.32

Appendix D-VI.1b (Continued).

Poly.#	Soil	SN6	SN5	SN4	SN5/SN6	SN4/SN6
681	CYG	129	166	168	1.29	1.3
682	BEN	126	161	163	1.28	1.29
683	HUB	131	161	163	1.23	1.24
684	CAR	118	152	154	1.28	1.3
686	LOB	122	161	162	1.32	1.33
689	CAR	114	148	150	1.3	1.31
690	RMY	130	164	167	1.26	1.28
691	HUB	122	151	154	1.24	1.26
692	BTN	129	159	162	1.24	1.26
693	RMY	139	174	176	1.25	1.26
694	HUB	135	167	169	1.23	1.25
695	BTN	135	165	168	1.22	1.24
696	BTN	135	164	166	1.21	1.23
698	MYW	129	154	156	1.19	1.21
699	HUB	133	160	162	1.2	1.21
702	CVL	142	174	177	1.23	1.25
703	HGV	135	162	165	1.2	1.22
705	MCO	131	154	155	1.18	1.18
708	MLA	129	153	155	1.18	1.19
709	COA	129	152	155	1.18	1.2
710	COA	137	166	169	1.21	1.23
711	COA	132	157	159	1.19	1.21
715	KVG	135	162	165	1.19	1.22

Appendix D-VI.1c: Dryland corn yields (g/m^2) averaged by Alberta Soil Landscape polygones for historical (1x; SN6) and doubled (2x; SN4 and SN5) atmospheric CO_2 concentrations. 0 represents areas without sufficient heat for corn to growth under current climate.

Poly.#	Soil	SN6	SN5	SN4	SN5/SN6	SN4/SN6
4	HZM	0	610	688	0	0
5	DON	0	604	685	0	0
9	BBN	0	603	686	0	0
10	BBN	0	580	673	0	0
11	ESH	0	585	675	0	0
13	HZM	0	624	685	0	0
14	COS	0	602	684	0	0
15	ABT	0	610	679	0	0
19	HZM	0	607	677	0	0
20	LAD	0	602	672	0	0
22	COS	0	619	665	0	0
27	DON	0	641	685	0	0
31	DVS	0	629	679	0	0
33	HRT	0	620	675	0	0
34	KNZ	0	625	677	0	0
47	DON	0	644	709	0	0
48	DON	0	609	681	0	0
49	TAG	0	607	678	0	0
51	SAD	0	572	665	0	0
52	VVW	0	602	673	0	0
53	TAG	0	616	675	0	0
54	ESH	0	563	663	0	0
56	ZBR	0	654	716	0	0
61	RYF	0	579	671	0	0
71	BBN	0	585	674	0	0
72	BLY	0	582	673	0	0
144	BBN	0	775	820	0	0
170	HUB	0	813	847	0	0
171	HUB	0	795	845	0	0
172	KTH	0	778	836	0	0
173	CUL	0	784	841	0	0
176	HRT	0	657	753	0	0
177	HRT	0	737	824	0	0
178	HPE	0	675	827	0	0
180	KNZ	0	699	829	0	0
182	ATO	0	665	826	0	0
185	UCS	0	660	812	0	0
189	CUL	0	659	760	0	0
192	COA	0	717	800	0	0
193	MLA	0	745	830	0	0
194	MLA	0	662	795	0	0
196	LNN	0	638	828	0	0
197	COA	0	652	812	0	0
198	COA	0	681	797	0	0
201	HRT	0	801	850	0	0
215	ABC	0	698	832	0	0
218	KNZ	0	632	823	0	0
227	TNW	0	610	815	0	0
231	ABC	0	582	805	0	0
248	GDI	0	528	771	0	0
252	UCS	0	647	828	0	0
253	COD	0	629	826	0	0
254	PIB	0	626	825	0	0
258	POK	0	562	798	0	0
259	RDW	0	590	813	0	0
261	NIT	0	574	813	0	0
264	COA	0	577	821	0	0
270	MPV	0	564	805	0	0
271	FLU	0	545	792	0	0
275	RDW	0	519	758	0	0
279	ABC	0	525	768	0	0
301	SDN	0	512	755	0	0
302	LCY	0	499	744	0	0
306	LCY	0	524	768	0	0
310	FRY	0	490	709	0	0
311	FRY	0	510	738	0	0
312	FRY	0	499	706	0	0
325	LCY	0	488	734	0	0
326	LCY	0	494	742	0	0
334	LCY	0	490	727	0	0
341	MGS	0	481	732	0	0
343	FRY	0	488	744	0	0
344	BSU	0	475	730	0	0
345	SDN	0	473	729	0	0
346	PHS	0	485	730	0	0
347	SDN	0	480	694	0	0
348	SDN	0	483	699	0	0
350	LFN	0	488	694	0	0
351	LFN	0	477	717	0	0
352	RDW	0	476	720	0	0
356	EOR	0	436	673	0	0
357	EOR	0	457	706	0	0
359	RED	0	452	709	0	0
360	EOR	0	458	716	0	0
362	EOR	0	443	711	0	0
363	EOR	0	431	700	0	0
364	EOR	0	433	698	0	0
365	HND	0	424	670	0	0
366	DCY	0	425	659	0	0
367	HND	0	429	669	0	0
370	HND	0	387	527	0	0
371	WWT	0	403	606	0	0
372	EOR	0	432	668	0	0
374	EOR	0	426	658	0	0
392	AGS	0	495	713	0	0
396	AGS	0	537	779	0	0
400	MGS	0	518	780	0	0
403	CMO	0	513	770	0	0
404	AGS	0	507	776	0	0
405	CMO	0	499	738	0	0
408	AGS	0	501	736	0	0
409	AGS	0	545	754	0	0
410	UCS	0	524	763	0	0
411	COA	0	548	770	0	0
412	CMO	0	508	729	0	0
416	WKN	0	520	782	0	0
418	MMO	0	594	797	0	0
420	TBY	0	620	796	0	0
421	HND	0	370	568	0	0
422	HCH	0	349	536	0	0
425	HND	0	316	549	0	0
426	MMO	0	580	793	0	0

Appendix D-VI.1c (Continued).

Poly.#	Soil	SN6	SN5	SN4	SN5/SN6	SN4/SN6
428	HND	0	283	481	0	0
429	FLU	0	561	771	0	0
430	MCO	0	562	765	0	0
431	AGS	0	590	769	0	0
432	KVG	0	612	793	0	0
433	POK	0	637	811	0	0
435	BTN	0	656	817	0	0
437	POK	0	621	792	0	0
439	COA	0	533	763	0	0
440	COA	0	628	796	0	0
441	MMO	0	583	792	0	0
442	WTB	0	628	815	0	0
443	HND	0	353	580	0	0
444	MET	0	388	626	0	0
450	LET	0	244	411	0	0
451	MET	185	225	382	1.21	2.06
453	CHN	186	216	369	1.16	1.99
457	MAB	179	200	347	1.11	1.93
458	MAB	165	186	332	1.13	2.01
460	WDN	171	191	337	1.12	1.97
461	BVL	182	203	351	1.12	1.93
463	HND	190	205	351	1.08	1.85
466	HND	0	227	387	0	0
468	HND	0	246	414	0	0
471	HUK	184	231	390	1.26	2.12
472	MAB	164	191	336	1.17	2.05
473	HND	183	214	366	1.17	1.99
474	MAB	173	201	348	1.16	2.01
475	BVL	172	204	351	1.19	2.04
476	MAB	166	201	345	1.21	2.07
478	CCL	180	215	366	1.19	2.04
480	HUK	0	245	407	0	0
481	YTW	0	249	413	0	0
484	WWT	0	293	490	0	0
486	YTW	0	258	433	0	0
487	HUK	178	208	343	1.17	1.93
489	HUK	197	234	393	1.19	1.99
494	LHD	0	341	560	0	0
496	MET	0	248	421	0	0
499	CVD	0	203	275	0	0
508	AGS	0	525	736	0	0
509	PHS	0	624	792	0	0
510	AGS	0	493	718	0	0
512	BVH	0	482	722	0	0
513	AGS	0	521	734	0	0
514	PHS	0	500	731	0	0
515	BVH	0	487	711	0	0
516	BVH	0	540	751	0	0
517	FLU	0	544	764	0	0
518	MGS	0	590	776	0	0
519	NVR	0	573	759	0	0
520	AGS	0	589	772	0	0
521	POK	0	625	794	0	0
523	PED	0	598	773	0	0
524	FLU	0	639	797	0	0
531	GDB	0	423	673	0	0
532	HKR	0	362	586	0	0
533	HND	0	329	544	0	0
534	MET	0	341	562	0	0
536	HND	0	378	601	0	0
537	BVH	0	442	667	0	0
538	HND	0	407	625	0	0
539	PHS	0	446	673	0	0
540	KLM	0	425	656	0	0
543	EOR	0	432	645	0	0
545	IRM	0	464	677	0	0
547	DEL	0	483	679	0	0
548	BVH	0	505	710	0	0
549	FLU	0	542	743	0	0
551	FLU	0	551	737	0	0
553	ATL	0	545	713	0	0
554	ATL	0	516	691	0	0
555	CYG	0	597	775	0	0
558	DEL	0	479	673	0	0
559	ATL	0	566	709	0	0
561	ATL	0	572	716	0	0
562	BGH	0	495	675	0	0
563	BSK	0	540	704	0	0
564	LET	215	363	516	1.69	2.4
565	DEL	0	470	666	0	0
566	DEL	0	403	610	0	0
567	BSK	0	443	634	0	0
568	DEL	0	442	637	0	0
569	IRM	0	460	649	0	0
570	HAN	0	403	604	0	0
571	HAN	250	327	545	1.3	2.17
572	DVG	0	436	569	0	0
574	LET	0	392	589	0	0
575	WWT	222	332	532	1.5	2.4
576	DMH	247	341	549	1.38	2.22
577	BZR	0	423	556	0	0
578	HAN	256	294	508	1.15	1.98
579	LET	225	318	521	1.41	2.31
581	HKR	224	281	477	1.25	2.13
582	HAN	0	304	516	0	0
583	HAN	252	296	499	1.17	1.97
584	DMH	256	349	568	1.36	2.22
589	HAN	0	290	497	0	0
590	CHN	150	170	315	1.13	2.09
591	BVL	157	182	329	1.16	2.09
592	FMT	158	186	337	1.18	2.13
593	CVD	156	187	336	1.19	2.15
595	ATP	139	177	335	1.28	2.41
596	FMT	157	206	385	1.31	2.45
598	FMT	159	210	390	1.32	2.45
599	MAB	164	191	352	1.16	2.15
600	CVD	161	202	371	1.26	2.31
601	MAB	171	197	339	1.15	1.98
602	MAB	171	194	345	1.13	2.02
603	MAB	173	206	373	1.19	2.16
605	HDY	190	209	368	1.1	1.94
606	CVD	193	209	324	1.09	1.68
607	CVD	199	223	356	1.12	1.78
608	MCT	207	234	406	1.13	1.96
609	TIY	211	222	376	1.05	1.78
610	BVL	201	226	399	1.12	1.98
611	HUK	209	229	404	1.1	1.94
613	CCL	212	243	449	1.15	2.12
615	CVD	198	239	421	1.2	2.12
616	CHN	185	225	414	1.22	2.24
617	FMT	174	219	404	1.26	2.32
618	CHN	165	218	399	1.32	2.41

Appendix D-VI.1c (Continued).

Poly.#	Soil	SN6	SN5	SN4	SN5/SN6	SN4/SN6
619	FMT	169	227	416	1.34	2.45
620	MAB	168	250	437	1.48	2.6
621	TTH	0	283	473	0	0
622	TTH	170	286	476	1.68	2.8
623	ZRB	165	291	480	1.76	2.9
624	THA	0	331	523	0	0
626	SIL	0	224	402	0	0
627	MAB	164	230	412	1.41	2.51
628	BVL	169	235	420	1.39	2.49
629	SIL	167	232	417	1.39	2.5
631	MAB	177	233	426	1.31	2.4
632	MAB	181	239	441	1.32	2.43
633	MAB	187	260	453	1.39	2.42
634	MAB	176	237	428	1.35	2.43
635	MAB	180	242	436	1.34	2.42
637	MSN	185	264	457	1.43	2.47
638	ZRB	181	242	437	1.34	2.41
639	PUR	193	319	483	1.65	2.5
641	MAB	195	256	446	1.31	2.28
642	MAB	194	237	434	1.22	2.23
643	CHN	212	257	437	1.21	2.06
645	DLB	0	379	521	0	0
648	CFD	194	227	395	1.17	2.03
649	BVL	206	242	441	1.18	2.14
650	MAB	207	237	434	1.15	2.1
651	RDM	211	259	456	1.23	2.16
653	LET	212	312	490	1.47	2.31
654	PUY	217	255	463	1.17	2.13
655	DEL	0	370	556	0	0
656	PUY	0	345	504	0	0
657	LET	211	335	482	1.58	2.28
658	CMY	0	323	443	0	0
659	DEL	0	407	568	0	0
660	CVD	209	238	428	1.14	2.04
661	RDM	209	255	446	1.22	2.13
663	LET	0	313	462	0	0
664	RDM	0	294	463	0	0
666	PUR	0	321	483	0	0
667	LET	221	335	489	1.52	2.21
669	LOB	0	619	748	0	0
671	PHS	0	587	742	0	0
672	PED	0	591	756	0	0
673	MMO	0	617	778	0	0
675	BTN	0	649	798	0	0
676	CYG	0	641	795	0	0
677	BEN	0	620	783	0	0
680	PNC	0	713	805	0	0
681	CYG	0	651	782	0	0
682	BEN	0	688	806	0	0
683	HUB	0	718	837	0	0
684	CAR	0	729	822	0	0
686	LOB	0	661	773	0	0
689	CAR	0	734	826	0	0
690	RMY	0	679	810	0	0
691	HUB	0	748	847	0	0
692	BTN	0	721	839	0	0
693	RMY	0	660	806	0	0
694	HUB	0	688	822	0	0
695	BTN	0	689	827	0	0
696	BTN	0	709	833	0	0
698	MYW	0	754	844	0	0
699	HUB	0	716	829	0	0
702	CVL	0	655	821	0	0
703	HGV	0	690	820	0	0
705	MCO	0	719	817	0	0
708	MLA	0	729	827	0	0
709	COA	0	719	830	0	0
710	COA	0	666	815	0	0
711	COA	0	695	821	0	0
715	KVG	0	654	804	0	0

Appendix D-VI.1d: Dryland crested wheatgrass yields (g/m^2) averaged by Alberta Soil Landscape polygones for historical (1x; SN6) and doubled (2x; SN4 and SN5) atmospheric CO_2 concentrations.

Poly.#	Soil	SN6	SN5	SN4	SN5/SN6	SN4/SN6
2	FAL	421	603	600	1.43	1.42
3	DON	429	567	559	1.32	1.3
4	HZM	442	574	548	1.3	1.24
5	DON	448	556	535	1.24	1.19
6	ESH	432	544	543	1.26	1.26
7	COS	424	595	586	1.4	1.38
9	BBN	431	591	558	1.37	1.29
10	BBN	451	526	509	1.17	1.13
11	ESH	447	500	507	1.12	1.13
13	HZM	424	595	577	1.4	1.36
14	COS	428	602	562	1.4	1.31
15	ABT	426	599	570	1.4	1.34
19	HZM	428	592	566	1.38	1.32
20	LAD	443	541	533	1.22	1.2
22	COS	429	581	587	1.35	1.37
27	DON	418	597	590	1.43	1.41
28	HZM	425	589	577	1.38	1.36
32	HRT	450	513	509	1.14	1.13
33	HRT	447	520	516	1.16	1.15
36	COS	443	517	518	1.17	1.17
47	DON	429	469	497	1.09	1.16
48	DON	444	477	486	1.07	1.09
49	TAG	449	489	492	1.09	1.1
51	SAD	465	474	473	1.02	1.02
52	VVW	452	507	503	1.12	1.11
53	TAG	445	527	523	1.19	1.18
54	ESH	468	452	458	0.97	0.98
56	ZBR	413	456	488	1.1	1.18
59	FAL	411	384	455	0.94	1.11
60	BBN	413	355	450	0.86	1.09
61	RYF	448	448	466	1	1.04
62	DVS	381	303	355	0.79	0.93
64	JUH	398	339	401	0.85	1.01
68	HRT	402	354	396	0.88	0.99
70	JUH	424	420	459	0.99	1.08
71	BBN	443	458	481	1.03	1.08
72	BLY	445	447	466	1	1.05
73	RYF	447	516	527	1.15	1.18
74	JUH	449	505	536	1.12	1.19
75	DIG	427	535	574	1.25	1.34
76	JUH	419	415	463	0.99	1.1
77	LAD	435	507	547	1.17	1.26
78	ABT	423	448	494	1.06	1.17
80	BWY	415	400	457	0.96	1.1
81	HZM	422	472	525	1.12	1.24
83	BUD	420	435	491	1.04	1.17
84	HZM	419	422	478	1.01	1.14
87	NPA	415	519	543	1.25	1.31
88	FAL	415	526	556	1.27	1.34
89	JUH	421	571	567	1.36	1.35
91	HZM	413	489	488	1.18	1.18
93	DON	413	534	555	1.29	1.34
94	HRT	427	532	576	1.25	1.35
97	FAL	412	379	463	0.92	1.12
98	HZM	411	446	505	1.08	1.23
99	CUL	419	430	529	1.03	1.26
101	FAL	412	391	455	0.95	1.1
102	WHW	417	400	465	0.96	1.12
103	ABT	422	425	478	1.01	1.13
104	HZM	422	426	482	1.01	1.14
105	CTE	424	454	514	1.07	1.21
107	ALC	418	480	516	1.15	1.23
108	HZM	420	427	477	1.02	1.14
109	PRV	418	438	486	1.05	1.16
110	CTE	424	470	528	1.11	1.24
112	ALC	425	446	494	1.05	1.16
130	DVS	337	260	305	0.77	0.91
132	CTE	364	321	369	0.88	1.01
133	BBN	421	500	567	1.19	1.35
135	DVS	416	442	515	1.06	1.24
144	BBN	397	777	785	1.95	1.97
170	HUB	400	901	867	2.25	2.17
171	HUB	435	838	855	1.93	1.97
172	KTH	465	821	807	1.77	1.74
173	CUL	471	832	811	1.76	1.72
176	HRT	459	616	676	1.34	1.47
177	HRT	458	761	810	1.66	1.77
178	HPE	483	699	756	1.45	1.56
180	KNZ	469	714	766	1.52	1.63
181	COS	464	719	758	1.55	1.63
182	ATO	479	694	762	1.45	1.59
185	UCS	480	682	748	1.42	1.56
189	CUL	461	623	684	1.35	1.48
192	COA	469	731	755	1.56	1.61
193	MLA	492	799	811	1.62	1.65
194	MLA	484	673	731	1.39	1.51
196	LNN	490	682	761	1.39	1.55
197	COA	502	693	752	1.38	1.5
198	COA	492	697	744	1.42	1.51
201	HRT	474	861	827	1.82	1.74
211	ZOR	463	682	733	1.47	1.58
212	ABC	463	642	721	1.39	1.56
215	ABC	464	658	727	1.42	1.57
218	KNZ	450	568	679	1.26	1.51
221	EGL	451	583	675	1.29	1.5
224	ABC	448	575	669	1.28	1.49
227	TNW	449	539	667	1.2	1.48
231	ABC	453	536	668	1.18	1.47
232	MLA	434	499	638	1.15	1.47
233	KNZ	438	519	649	1.19	1.48
236	ABC	454	530	675	1.17	1.49
240	KNZ	449	531	664	1.18	1.48
246	GDI	462	545	681	1.18	1.47
248	GDI	470	572	688	1.22	1.47
250	ABC	462	546	683	1.18	1.48
252	UCS	477	673	745	1.41	1.56
253	COD	483	660	746	1.37	1.54
254	PIB	490	668	753	1.36	1.54
258	POK	481	604	710	1.26	1.48
259	RDW	491	629	733	1.28	1.49
261	NIT	494	618	734	1.25	1.48
264	COA	501	619	745	1.23	1.49
268	KNZ	476	577	705	1.21	1.48
271	FLU	475	564	695	1.19	1.46

Appendix D-VI.1d (Continued).

Poly.#	Soil	SN6	SN5	SN4	SN5/SN6	SN4/SN6
275	RDW	443	503	645	1.13	1.46
279	ABC	452	520	667	1.15	1.47
290	ABC	473	586	697	1.24	1.47
291	LCY	460	582	702	1.27	1.53
292	TMN	447	558	678	1.25	1.51
296	NIT	391	412	524	1.05	1.34
297	GOG	441	535	656	1.21	1.48
301	SDN	409	447	568	1.09	1.39
302	LCY	393	418	531	1.06	1.35
306	LCY	448	516	661	1.15	1.47
310	FRY	400	453	586	1.13	1.47
311	FRY	430	481	626	1.12	1.46
312	FRY	404	441	585	1.09	1.45
315	NTW	434	502	617	1.15	1.42
316	LCY	439	504	622	1.15	1.42
317	LCY	435	513	632	1.18	1.45
320	FRY	437	503	626	1.15	1.43
322	LCY	437	553	648	1.27	1.48
323	LCY	436	544	645	1.25	1.48
325	LCY	430	518	628	1.21	1.46
326	LCY	404	451	564	1.12	1.4
334	LCY	416	501	632	1.2	1.52
335	FRY	425	540	635	1.27	1.49
337	MGS	404	499	588	1.23	1.45
339	LFN	404	497	587	1.23	1.45
341	MGS	422	524	625	1.24	1.48
342	LFN	427	535	649	1.25	1.52
343	FRY	431	542	663	1.26	1.54
344	BSU	433	509	618	1.18	1.43
345	SDN	437	503	614	1.15	1.4
346	PHS	422	510	634	1.21	1.5
347	SDN	393	433	562	1.1	1.43
348	SDN	396	448	579	1.13	1.46
350	LFN	382	411	547	1.08	1.43
351	LFN	417	468	585	1.12	1.4
352	RDW	420	471	586	1.12	1.4
354	BVH	396	478	569	1.21	1.44
356	EOR	371	472	557	1.27	1.5
357	EOR	398	483	574	1.21	1.44
359	RED	408	491	576	1.2	1.41
360	EOR	416	492	582	1.18	1.4
362	EOR	403	488	585	1.21	1.45
363	EOR	392	483	577	1.23	1.47
364	EOR	368	465	560	1.26	1.52
365	HND	366	447	542	1.22	1.48
366	DCY	373	446	537	1.2	1.44
367	HND	377	454	543	1.2	1.44
370	HND	329	342	437	1.04	1.33
371	WWT	349	433	514	1.24	1.47
372	EOR	377	460	540	1.22	1.43
374	EOR	366	467	548	1.27	1.49
375	WWT	350	462	539	1.32	1.54
376	HND	342	464	535	1.36	1.57
378	HND	335	470	537	1.4	1.6
392	AGS	406	438	580	1.08	1.43
393	LIZ	461	521	666	1.13	1.44
396	AGS	467	544	663	1.16	1.42
401	MGS	465	557	681	1.2	1.46
403	CMO	454	501	637	1.1	1.4
404	AGS	459	509	657	1.11	1.43
405	CMO	427	464	605	1.09	1.42
408	AGS	423	454	576	1.07	1.36
409	AGS	443	509	601	1.15	1.36
410	UCS	451	504	624	1.12	1.38
411	COA	459	529	638	1.15	1.39
412	CMO	417	458	561	1.1	1.35
416	WKN	468	564	680	1.21	1.45
418	MMO	493	633	714	1.28	1.45
420	TBY	501	665	724	1.32	1.44
421	HND	326	374	465	1.15	1.42
422	HCH	302	350	433	1.16	1.43
423	LET	285	362	435	1.27	1.52
425	HND	298	370	456	1.24	1.53
426	MMO	491	596	686	1.21	1.4
428	HND	270	317	392	1.17	1.45
429	FLU	461	541	641	1.17	1.39
430	MCO	455	541	630	1.19	1.38
431	AGS	462	570	641	1.23	1.39
432	KVG	492	616	683	1.25	1.39
433	POK	518	649	711	1.25	1.37
435	BTN	517	683	727	1.32	1.41
437	POK	490	630	687	1.29	1.4
439	COA	451	511	622	1.13	1.38
440	COA	513	669	720	1.3	1.4
441	MMO	493	617	699	1.25	1.42
442	WTB	529	643	710	1.22	1.34
443	HND	321	387	476	1.21	1.48
444	MET	335	400	489	1.19	1.46
449	KUR	233	275	346	1.18	1.48
451	MET	200	252	311	1.26	1.56
452	LET	210	254	318	1.21	1.51
453	CHN	194	252	309	1.3	1.59
457	MAB	172	242	289	1.41	1.68
458	MAB	151	229	266	1.51	1.75
460	WDN	158	233	272	1.47	1.72
461	BVL	177	241	291	1.36	1.64
463	HND	182	251	301	1.38	1.65
466	HND	203	251	313	1.24	1.54
467	WWT	222	263	330	1.19	1.49
471	HUK	214	252	314	1.18	1.47
472	MAB	158	224	269	1.41	1.7
473	HND	196	243	300	1.24	1.53
474	MAB	173	232	282	1.34	1.63
475	BVL	179	228	283	1.27	1.58
476	MAB	174	218	276	1.25	1.59
478	CCL	197	234	295	1.19	1.5
480	HUK	248	266	329	1.07	1.33
481	YTW	261	274	337	1.05	1.29
484	WWT	286	310	389	1.08	1.36
486	YTW	259	271	341	1.05	1.32
487	HUK	173	210	255	1.21	1.47
489	HUK	220	229	284	1.04	1.29
494	LHD	306	345	430	1.13	1.4
496	MET	242	237	297	0.98	1.23
499	CVD	116	133	150	1.15	1.29
508	AGS	427	552	625	1.29	1.46
509	PHS	488	646	698	1.32	1.43
510	AGS	406	475	566	1.17	1.39
512	BVH	414	567	641	1.37	1.55
513	AGS	423	532	610	1.26	1.44
514	PHS	438	596	664	1.36	1.52
515	BVH	443	582	646	1.31	1.46

Appendix D-VI.1d (Continued).

Poly.#	Soil	SN6	SN5	SN4	SN5/SN6	SN4/SN6
516	BVH	464	648	708	1.4	1.53
517	FLU	462	650	714	1.41	1.54
518	MGS	480	673	731	1.4	1.52
519	NVR	453	588	652	1.3	1.44
520	AGS	468	623	683	1.33	1.46
521	POK	494	682	734	1.38	1.49
523	PED	493	721	769	1.46	1.56
524	FLU	505	725	779	1.44	1.54
531	GDB	374	498	578	1.33	1.55
532	HKR	325	389	472	1.2	1.45
533	HND	316	336	427	1.06	1.35
534	MET	322	330	439	1.02	1.36
536	HND	352	387	490	1.1	1.39
537	BVH	399	512	584	1.28	1.46
538	HND	384	453	526	1.18	1.37
539	PHS	396	514	588	1.3	1.49
540	KLM	376	487	564	1.3	1.5
543	EOR	411	505	561	1.23	1.37
545	IRM	435	557	611	1.28	1.4
547	DEL	447	591	636	1.32	1.42
548	BVH	459	618	672	1.35	1.46
549	FLU	469	653	708	1.39	1.51
551	FLU	484	694	738	1.43	1.52
553	ATL	508	707	737	1.39	1.45
554	ATL	506	751	755	1.48	1.49
555	CYG	510	766	806	1.5	1.58
558	DEL	530	738	736	1.39	1.39
559	ATL	391	814	821	2.08	2.1
561	ATL	431	790	795	1.83	1.84
562	BGH	462	734	737	1.59	1.6
563	BSK	519	729	748	1.41	1.44
564	LET	466	661	604	1.42	1.3
565	DEL	536	724	725	1.35	1.35
566	DEL	493	627	625	1.27	1.27
567	BSK	480	610	623	1.27	1.3
568	DEL	430	537	575	1.25	1.34
569	IRM	458	587	618	1.28	1.35
570	HAN	428	489	524	1.14	1.23
571	HAN	309	304	406	0.98	1.31
572	DVG	410	614	599	1.5	1.46
574	LET	449	487	518	1.08	1.15
575	WWT	402	445	433	1.11	1.08
576	DMH	373	404	427	1.08	1.15
577	BZR	440	582	554	1.32	1.26
578	HAN	303	344	346	1.14	1.14
579	LET	385	415	409	1.08	1.06
581	HKR	278	283	347	1.02	1.25
582	HAN	287	299	348	1.04	1.21
583	HAN	282	290	350	1.03	1.24
584	DMH	337	356	430	1.06	1.28
589	HAN	273	290	319	1.06	1.17
590	CHN	125	221	248	1.76	1.98
591	BVL	146	235	273	1.6	1.86
592	FMT	158	262	307	1.65	1.94
593	CVD	156	251	302	1.61	1.93
595	ATP	154	286	392	1.86	2.55
596	FMT	202	339	388	1.68	1.92
598	FMT	207	347	390	1.67	1.88
599	MAB	166	334	344	2	2.06
600	CVD	198	330	362	1.67	1.83
601	MAB	166	245	276	1.48	1.67
602	MAB	163	295	305	1.8	1.86
603	MAB	246	346	361	1.4	1.47
605	HDY	207	301	300	1.45	1.45
606	CVD	157	206	211	1.31	1.34
607	CVD	186	231	240	1.24	1.29
608	MCT	238	309	305	1.3	1.28
609	TIY	191	261	249	1.37	1.3
610	BVL	297	374	359	1.26	1.21
611	HUK	258	327	302	1.26	1.17
613	CCL	280	372	361	1.33	1.29
615	CVD	352	496	464	1.41	1.32
616	CHN	304	459	443	1.51	1.46
617	FMT	241	384	415	1.59	1.72
618	CHN	224	362	399	1.61	1.78
619	FMT	228	382	413	1.68	1.81
620	MAB	224	418	432	1.87	1.93
621	TTH	262	493	503	1.88	1.92
622	TTH	257	496	500	1.93	1.95
623	ZRB	243	494	491	2.03	2.02
624	THA	285	579	570	2.03	2
626	SIL	124	309	309	2.49	2.49
627	MAB	164	352	352	2.14	2.14
628	BVL	204	391	392	1.92	1.92
629	SIL	185	372	375	2.01	2.02
631	MAB	250	427	441	1.71	1.76
632	MAB	318	552	532	1.74	1.67
633	MAB	353	585	540	1.66	1.53
634	MAB	254	440	439	1.74	1.73
635	MAB	290	489	478	1.68	1.65
637	MSN	360	597	548	1.66	1.52
638	ZRB	299	508	492	1.69	1.64
639	PUR	395	568	472	1.44	1.2
641	MAB	355	563	520	1.59	1.46
642	MAB	351	539	484	1.53	1.38
643	CHN	368	547	509	1.49	1.38
645	DLB	431	567	456	1.31	1.06
648	CFD	347	423	413	1.22	1.19
649	BVL	416	533	534	1.28	1.28
650	MAB	372	465	445	1.25	1.2
651	RDM	360	412	350	1.14	0.97
653	LET	425	466	393	1.1	0.92
654	PUY	291	377	369	1.3	1.27
655	DEL	448	570	536	1.27	1.2
656	PUY	439	527	459	1.2	1.05
657	LET	421	561	511	1.33	1.21
658	CMY	398	488	408	1.22	1.02
659	DEL	455	633	597	1.39	1.31
660	CVD	270	348	334	1.29	1.24
661	RDM	371	451	408	1.21	1.1
663	LET	413	524	468	1.27	1.13
664	RDM	405	482	422	1.19	1.04
666	PUR	397	566	473	1.42	1.19
667	LET	414	582	510	1.41	1.23
669	LOB	438	810	818	1.85	1.87
671	PHS	492	761	785	1.55	1.6
672	PED	498	761	792	1.53	1.59
673	MMO	496	782	815	1.58	1.64
675	BTN	500	776	814	1.55	1.63
676	CYG	503	750	799	1.49	1.59
677	BEN	500	777	812	1.55	1.62
680	PNC	442	849	858	1.92	1.94

Appendix D-VI.1d (Continued).

Poly.#	Soil	SN6	SN5	SN4	SN5/SN6	SN4/SN6
681	CYG	470	808	829	1.72	1.76
682	BEN	478	832	850	1.74	1.78
683	HUB	522	827	850	1.59	1.63
684	CAR	464	865	873	1.86	1.88
686	LOB	438	831	840	1.9	1.91
689	CAR	429	854	851	1.99	1.98
690	RMY	494	817	841	1.66	1.7
691	HUB	502	886	890	1.76	1.77
692	BTN	516	852	869	1.65	1.68
693	RMY	508	759	805	1.49	1.58
694	HUB	514	773	808	1.5	1.57
695	BTN	521	739	774	1.42	1.48
696	BTN	528	765	800	1.45	1.51
698	MYW	527	840	863	1.59	1.64
699	HUB	526	752	788	1.43	1.5
702	CVL	533	672	728	1.26	1.37
703	HGV	524	702	747	1.34	1.42
705	MCO	523	689	728	1.32	1.39
708	MLA	518	756	784	1.46	1.51
709	COA	527	766	800	1.45	1.52
710	COA	521	698	746	1.34	1.43
711	COA	524	735	775	1.4	1.48
715	KVG	509	699	747	1.38	1.47

Appendix D-VI.2a: Fallow-canola yields (g/m^2) averaged by Alberta Soil Landscape polygones for historical (1x; SN6) and doubled (2x; SN4 and SN5) atmospheric CO_2 concentrations.

Poly.#	Soil	SN6	SN5	SN4	SN5/SN6	SN4/SN6
2	FAL	210	342	345	1.63	1.64
3	DON	217	334	340	1.54	1.56
4	HZM	225	333	341	1.48	1.51
5	DON	231	328	337	1.42	1.46
6	ESH	225	330	338	1.46	1.5
7	COS	212	338	342	1.59	1.62
9	BBN	213	329	336	1.55	1.58
10	BBN	223	309	322	1.39	1.45
11	ESH	231	307	319	1.33	1.38
13	HZM	204	320	326	1.57	1.6
14	COS	207	325	333	1.57	1.61
15	ABT	204	319	327	1.57	1.6
19	HZM	205	318	325	1.55	1.59
20	LAD	214	307	316	1.43	1.48
22	COS	203	308	314	1.51	1.55
27	DON	191	307	312	1.6	1.63
28	HZM	212	334	339	1.58	1.6
32	HRT	217	304	307	1.4	1.41
33	HRT	216	305	309	1.41	1.43
36	COS	213	301	305	1.41	1.43
47	DON	223	297	308	1.33	1.38
48	DON	223	297	308	1.33	1.38
49	TAG	222	299	308	1.35	1.39
51	SAD	228	294	310	1.29	1.36
52	VVW	220	302	311	1.37	1.41
53	TAG	215	305	311	1.42	1.45
54	ESH	233	291	308	1.25	1.32
56	ZBR	220	299	306	1.36	1.39
59	FAL	235	293	307	1.25	1.31
60	BBN	241	292	311	1.21	1.29
61	RYF	233	295	309	1.27	1.33
62	DVS	228	277	284	1.21	1.24
64	JUH	232	285	295	1.23	1.27
68	HRT	229	284	293	1.24	1.28
70	JUH	236	295	305	1.25	1.29
71	BBN	235	299	312	1.27	1.33
72	BLY	233	296	309	1.27	1.33
73	RYF	235	313	324	1.33	1.38
74	JUH	243	310	322	1.28	1.32
75	DIG	229	322	331	1.4	1.44
76	JUH	236	296	305	1.25	1.29
77	LAD	236	314	324	1.33	1.37
78	ABT	235	303	312	1.29	1.33
80	BWY	232	295	300	1.27	1.29
81	HZM	232	308	316	1.33	1.36
83	BUD	232	302	308	1.3	1.33
84	HZM	232	300	305	1.29	1.31
87	NPA	220	327	335	1.49	1.53
88	FAL	221	328	336	1.48	1.52
89	JUH	211	336	340	1.6	1.62
91	HZM	209	325	331	1.55	1.58
93	DON	218	333	341	1.53	1.57
94	HRT	230	321	330	1.39	1.43
97	FAL	237	295	308	1.24	1.3
98	HZM	231	303	310	1.31	1.34
99	CUL	236	305	316	1.29	1.34
101	FAL	233	294	301	1.26	1.29
102	WHW	234	296	301	1.27	1.29
103	ABT	233	299	305	1.29	1.31
104	HZM	234	301	306	1.28	1.31
105	CTE	238	310	315	1.3	1.32
107	ALC	225	314	320	1.39	1.42
108	HZM	231	299	304	1.29	1.31
109	PRV	233	303	307	1.3	1.32
110	CTE	240	315	320	1.31	1.33
112	ALC	236	306	310	1.29	1.31
130	DVS	202	246	254	1.22	1.26
132	CTE	190	270	279	1.42	1.47
133	BBN	234	312	324	1.34	1.39
135	DVS	235	303	318	1.29	1.35
144	BBN	200	345	349	1.73	1.75
170	HUB	196	364	363	1.85	1.85
171	HUB	223	355	358	1.59	1.6
172	KTH	242	348	353	1.44	1.46
173	CUL	245	352	357	1.43	1.45
176	HRT	248	280	296	1.13	1.19
177	HRT	249	332	342	1.34	1.38
178	HPE	280	328	348	1.17	1.24
180	KNZ	267	329	346	1.23	1.3
181	COS	265	333	349	1.26	1.32
182	ATO	278	326	348	1.17	1.25
185	UCS	276	318	339	1.15	1.23
189	CUL	251	284	301	1.13	1.2
192	COA	251	319	329	1.27	1.31
193	MLA	262	344	349	1.31	1.33
194	MLA	273	310	327	1.14	1.2
196	LNN	291	327	353	1.12	1.21
197	COA	290	321	339	1.11	1.17
198	COA	272	315	328	1.16	1.21
201	HRT	244	361	363	1.48	1.49
211	ZOR	266	324	343	1.22	1.29
212	ABC	265	312	333	1.18	1.25
215	ABC	267	316	336	1.18	1.26
218	KNZ	266	282	311	1.06	1.17
221	EGL	267	297	321	1.11	1.2
224	ABC	266	291	317	1.09	1.19
227	TNW	267	274	305	1.03	1.14
231	ABC	270	274	305	1.02	1.13
232	MLA	260	257	292	0.99	1.12
233	KNZ	261	267	299	1.02	1.14
236	ABC	269	287	312	1.07	1.16
240	KNZ	267	275	305	1.03	1.14
246	GDI	270	284	308	1.05	1.14
248	GDI	271	280	304	1.03	1.12
250	ABC	271	282	306	1.04	1.13
252	UCS	280	322	345	1.15	1.23
253	COD	285	320	344	1.12	1.21
254	PIB	292	323	348	1.11	1.2
258	POK	294	302	327	1.03	1.11
259	RDW	292	312	336	1.07	1.15
261	NIT	294	312	335	1.06	1.14
264	COA	293	315	337	1.07	1.15
268	KNZ	281	294	321	1.05	1.14
271	FLU	284	295	319	1.04	1.12
275	RDW	266	272	298	1.02	1.12
279	ABC	268	279	303	1.04	1.13
290	ABC	273	282	306	1.03	1.12
291	LCY	274	283	306	1.03	1.12
292	TMN	277	279	303	1.01	1.09
296	NIT	231	212	241	0.92	1.04

Appendix D-VI.2a (Continued).

Poly.#	Soil	SN6	SN5	SN4	SN5/SN6	SN4/SN6
297	GOG	263	266	290	1.01	1.1
301	SDN	243	233	261	0.96	1.08
302	LCY	235	218	248	0.93	1.05
306	LCY	265	276	300	1.04	1.13
310	FRY	244	247	276	1.01	1.13
311	FRY	257	265	290	1.03	1.13
312	FRY	242	248	274	1.02	1.13
315	NTW	273	264	291	0.97	1.07
316	LCY	276	269	295	0.97	1.07
317	LCY	266	263	288	0.99	1.08
320	FRY	267	263	288	0.99	1.08
322	LCY	274	276	303	1.01	1.1
323	LCY	274	276	302	1.01	1.1
325	LCY	267	266	294	1	1.1
326	LCY	245	235	265	0.96	1.08
334	LCY	259	268	297	1.03	1.15
335	FRY	269	272	300	1.01	1.12
337	MGS	269	276	304	1.03	1.13
339	LFN	269	277	306	1.03	1.13
341	MGS	269	276	305	1.03	1.13
342	LFN	271	282	311	1.04	1.15
343	FRY	273	286	316	1.05	1.16
344	BSU	272	283	311	1.04	1.14
345	SDN	272	284	312	1.04	1.14
346	PHS	266	276	306	1.04	1.15
347	SDN	248	252	279	1.02	1.13
348	SDN	247	253	281	1.02	1.14
350	LFN	251	252	276	1	1.1
351	LFN	266	273	300	1.03	1.13
352	RDW	271	279	304	1.03	1.12
354	BVH	269	279	308	1.03	1.14
356	EOR	256	279	304	1.09	1.19
357	EOR	266	279	308	1.05	1.16
359	RED	269	280	315	1.04	1.17
360	EOR	271	282	314	1.04	1.16
362	EOR	273	277	307	1.01	1.13
363	EOR	272	275	306	1.01	1.12
364	EOR	272	288	315	1.06	1.16
365	HND	264	269	299	1.02	1.13
366	DCY	261	261	293	1	1.12
367	HND	262	264	296	1	1.13
370	HND	231	203	231	0.88	1
371	WWT	248	244	283	0.98	1.14
372	EOR	259	264	300	1.02	1.16
374	EOR	255	271	302	1.06	1.18
375	WWT	250	262	298	1.05	1.19
376	HND	249	251	297	1.01	1.2
378	HND	248	243	298	0.98	1.2
392	AGS	251	253	279	1.01	1.11
393	LIZ	281	286	312	1.02	1.11
396	AGS	291	289	315	0.99	1.08
401	MGS	295	289	317	0.98	1.07
403	CMO	282	282	309	1	1.1
404	AGS	281	286	312	1.02	1.11
405	CMO	265	267	293	1.01	1.11
408	AGS	271	267	296	0.98	1.09
409	AGS	281	274	308	0.98	1.1
410	UCS	284	279	307	0.98	1.08

Poly.#	Soil	SN6	SN5	SN4	SN5/SN6	SN4/SN6
411	COA	293	283	308	0.96	1.05
412	CMO	273	269	303	0.99	1.11
416	WKN	298	289	317	0.97	1.06
418	MMO	295	306	327	1.04	1.11
420	TBY	295	309	327	1.05	1.11
421	HND	237	225	266	0.95	1.12
422	HCH	227	210	251	0.92	1.1
423	LET	226	211	257	0.93	1.14
425	HND	227	223	284	0.98	1.25
426	MMO	299	302	325	1.01	1.09
428	HND	204	201	265	0.98	1.3
429	FLU	295	285	309	0.97	1.05
430	MCO	288	282	312	0.98	1.08
431	AGS	287	285	317	0.99	1.11
432	KVG	295	305	329	1.03	1.11
433	POK	300	320	340	1.07	1.13
435	BTN	298	324	342	1.09	1.15
437	POK	292	306	331	1.05	1.14
439	COA	286	280	308	0.98	1.08
440	COA	299	311	328	1.04	1.09
441	MMO	299	303	325	1.01	1.09
442	WTB	306	322	343	1.05	1.12
443	HND	239	234	285	0.98	1.19
444	MET	255	257	299	1.01	1.17
449	KUR	190	188	245	0.99	1.29
451	MET	168	177	244	1.06	1.45
452	LET	174	181	245	1.04	1.41
453	CHN	164	174	243	1.06	1.48
457	MAB	152	165	236	1.08	1.55
458	MAB	142	155	228	1.09	1.6
460	WDN	145	158	230	1.09	1.59
461	BVL	153	165	237	1.08	1.55
463	HND	158	171	241	1.09	1.53
466	HND	169	178	245	1.05	1.45
467	WWT	180	184	247	1.02	1.37
471	HUK	169	175	247	1.03	1.46
472	MAB	142	158	231	1.12	1.63
473	HND	160	168	243	1.05	1.52
474	MAB	149	161	236	1.08	1.59
475	BVL	149	160	240	1.08	1.61
476	MAB	145	162	237	1.12	1.64
478	CCL	156	163	246	1.04	1.57
480	HUK	176	174	251	0.99	1.43
481	YTW	178	174	253	0.98	1.42
484	WWT	209	207	272	0.99	1.3
486	YTW	186	188	260	1.01	1.4
487	HUK	145	157	227	1.09	1.57
489	HUK	169	179	249	1.06	1.47
494	LHD	235	234	287	0.99	1.22
496	MET	182	194	263	1.07	1.44
499	CVD	113	117	162	1.03	1.43
508	AGS	275	281	320	1.02	1.16
509	PHS	289	308	334	1.07	1.16
510	AGS	271	272	310	1	1.15
512	BVH	271	285	327	1.05	1.21
513	AGS	275	278	317	1.01	1.15
514	PHS	272	299	334	1.1	1.23
515	BVH	266	300	331	1.13	1.25

Appendix D-VI.2a (Continued).

Poly.#	Soil	SN6	SN5	SN4	SN5/SN6	SN4/SN6
516	BVH	274	310	342	1.13	1.25
517	FLU	281	311	345	1.11	1.23
518	MGS	280	314	344	1.12	1.23
519	NVR	280	288	325	1.03	1.16
520	AGS	283	299	331	1.06	1.17
521	POK	286	317	342	1.11	1.2
523	PED	273	324	351	1.19	1.29
524	FLU	284	327	352	1.15	1.24
531	GDB	261	269	317	1.03	1.21
532	HKR	241	243	295	1.01	1.23
533	HND	230	239	293	1.04	1.27
534	MET	237	252	303	1.07	1.28
536	HND	247	267	313	1.08	1.27
537	BVH	259	280	322	1.08	1.24
538	HND	251	274	317	1.09	1.26
539	PHS	261	279	322	1.07	1.23
540	KLM	259	269	317	1.04	1.23
543	EOR	255	282	321	1.11	1.26
545	IRM	259	293	327	1.13	1.26
547	DEL	255	297	331	1.17	1.3
548	BVH	261	305	335	1.17	1.29
549	FLU	269	312	341	1.16	1.27
551	FLU	262	318	346	1.22	1.32
553	ATL	254	318	343	1.25	1.35
554	ATL	218	319	335	1.46	1.54
555	CYG	275	333	359	1.21	1.3
558	DEL	222	318	339	1.43	1.53
559	ATL	154	308	290	2	1.88
561	ATL	181	315	315	1.74	1.74
562	BGH	192	305	314	1.59	1.63
563	BSK	243	319	340	1.31	1.4
564	LET	174	245	279	1.41	1.6
565	DEL	227	317	343	1.4	1.51
566	DEL	211	295	330	1.4	1.56
567	BSK	230	295	328	1.28	1.43
568	DEL	248	285	323	1.15	1.3
569	IRM	242	294	327	1.21	1.35
570	HAN	240	275	318	1.14	1.32
571	HAN	230	249	302	1.08	1.31
572	DVG	152	286	297	1.88	1.95
574	LET	231	274	316	1.19	1.37
575	WWT	210	251	305	1.19	1.45
576	DMH	222	251	306	1.13	1.38
577	BZR	165	281	303	1.7	1.84
578	HAN	206	229	296	1.11	1.44
579	LET	209	244	302	1.17	1.44
581	HKR	204	213	276	1.04	1.35
582	HAN	215	233	293	1.08	1.36
583	HAN	210	225	286	1.07	1.36
584	DMH	235	258	309	1.1	1.31
589	HAN	206	224	288	1.09	1.39
590	CHN	130	145	220	1.12	1.69
591	BVL	137	154	228	1.13	1.67
592	FMT	139	157	233	1.13	1.68
593	CVD	138	157	234	1.14	1.7
595	ATP	128	147	250	1.15	1.96
596	FMT	155	179	264	1.16	1.7
598	FMT	157	182	264	1.16	1.68
599	MAB	146	164	231	1.12	1.58
600	CVD	156	176	243	1.13	1.56
601	MAB	142	160	226	1.13	1.59

Poly.#	Soil	SN6	SN5	SN4	SN5/SN6	SN4/SN6
602	MAB	145	162	226	1.12	1.56
603	MAB	164	178	239	1.09	1.46
605	HDY	160	176	237	1.1	1.48
606	CVD	137	147	201	1.07	1.46
607	CVD	146	157	218	1.07	1.49
608	MCT	165	180	253	1.09	1.53
609	TIY	165	181	240	1.1	1.45
610	BVL	173	190	251	1.1	1.45
611	HUK	170	187	258	1.1	1.51
613	CCL	179	196	282	1.09	1.57
615	CVD	176	202	262	1.15	1.49
616	CHN	173	195	261	1.13	1.51
617	FMT	169	190	258	1.12	1.52
618	CHN	167	189	256	1.14	1.54
619	FMT	169	196	268	1.16	1.58
620	MAB	168	211	280	1.26	1.67
621	TTH	175	230	289	1.32	1.65
622	TTH	173	233	292	1.34	1.68
623	ZRB	172	238	296	1.38	1.72
624	THA	180	261	308	1.45	1.71
626	SIL	156	201	282	1.29	1.81
627	MAB	158	203	280	1.28	1.77
628	BVL	161	204	278	1.27	1.73
629	SIL	160	203	279	1.27	1.75
631	MAB	164	199	272	1.21	1.66
632	MAB	165	201	278	1.22	1.68
633	MAB	168	210	280	1.25	1.67
634	MAB	162	202	275	1.25	1.7
635	MAB	164	203	276	1.24	1.68
637	MSN	168	212	282	1.26	1.68
638	ZRB	164	203	276	1.24	1.68
639	PUR	161	229	279	1.43	1.74
641	MAB	173	211	276	1.22	1.6
642	MAB	176	205	272	1.16	1.55
643	CHN	179	215	271	1.2	1.51
645	DLB	165	254	291	1.54	1.77
648	CFD	174	189	246	1.09	1.42
649	BVL	187	212	268	1.13	1.43
650	MAB	182	203	270	1.12	1.48
651	RDM	182	208	287	1.14	1.58
653	LET	187	229	286	1.23	1.53
654	PUY	184	203	286	1.1	1.55
655	DEL	189	269	303	1.43	1.6
656	PUY	174	240	274	1.38	1.57
657	LET	165	230	255	1.39	1.54
658	CMY	150	203	206	1.35	1.37
659	DEL	179	286	295	1.6	1.65
660	CVD	174	190	270	1.09	1.55
661	RDM	180	207	275	1.15	1.52
663	LET	166	217	243	1.31	1.47
664	RDM	176	217	266	1.23	1.51
666	PUR	151	215	260	1.42	1.73
667	LET	174	245	285	1.41	1.64
669	LOB	192	325	329	1.69	1.72
671	PHS	238	325	342	1.37	1.44
672	PED	253	328	350	1.3	1.38
673	MMO	253	332	353	1.32	1.4
675	BTN	261	333	353	1.28	1.36
676	CYG	274	330	354	1.21	1.29
677	BEN	261	333	354	1.28	1.36
680	PNC	168	333	334	1.98	1.99

Appendix D-VI.2a (Continued).

Poly.#	Soil	SN6	SN5	SN4	SN5/SN6	SN4/SN6
681	CYG	213	332	343	1.56	1.61
682	BEN	213	338	347	1.58	1.63
683	HUB	263	345	354	1.31	1.35
684	CAR	184	340	342	1.85	1.86
686	LOB	180	330	332	1.83	1.85
689	CAR	183	328	326	1.79	1.78
690	RMY	239	338	352	1.42	1.47
691	HUB	224	349	352	1.56	1.57
692	BTN	246	348	358	1.42	1.46
693	RMY	275	332	354	1.21	1.29
694	HUB	273	336	350	1.23	1.28
695	BTN	290	332	345	1.15	1.19
696	BTN	286	338	347	1.18	1.21
698	MYW	270	349	349	1.29	1.29
699	HUB	283	338	345	1.19	1.22
702	CVL	303	328	346	1.08	1.14
703	HGV	292	332	342	1.14	1.17
705	MCO	286	334	340	1.17	1.19
708	MLA	279	341	346	1.23	1.24
709	COA	288	343	350	1.19	1.21
710	COA	296	326	340	1.1	1.15
711	COA	292	334	344	1.15	1.18
715	KVG	292	319	334	1.09	1.14

Appendix D-VI.2b: Fallow-spring wheat rotation yields (g/m^2) averaged by Alberta Soil Landscape polygones for historical (1x; SN6) and doubled (2x; SN4 and SN5) atmospheric CO_2 concentrations.

Poly.#	Soil	SN6	SN5	SN4	SN5/SN6	SN4/SN6
2	FAL	178	220	210	1.24	1.18
3	DON	186	230	221	1.24	1.19
4	HZM	188	232	221	1.23	1.18
5	DON	192	236	225	1.23	1.17
6	ESH	192	237	230	1.24	1.2
7	COS	183	227	216	1.24	1.18
9	BBN	201	252	239	1.25	1.19
10	BBN	210	260	245	1.24	1.17
11	ESH	209	257	243	1.23	1.16
13	HZM	198	247	233	1.25	1.18
14	COS	209	264	249	1.26	1.19
15	ABT	206	260	245	1.26	1.18
19	HZM	207	260	245	1.26	1.18
20	LAD	205	254	238	1.24	1.16
22	COS	198	246	230	1.24	1.16
27	DON	185	227	212	1.23	1.14
28	HZM	187	232	221	1.24	1.18
32	HRT	203	249	230	1.23	1.14
33	HRT	203	250	231	1.23	1.14
36	COS	198	242	224	1.22	1.13
47	DON	198	242	228	1.22	1.15
48	DON	203	249	233	1.22	1.15
49	TAG	204	250	233	1.23	1.14
51	SAD	211	259	241	1.23	1.14
52	VVW	205	253	236	1.23	1.15
53	TAG	202	249	232	1.23	1.15
54	ESH	212	259	242	1.22	1.14
56	ZBR	201	246	236	1.22	1.18
59	FAL	198	240	233	1.21	1.17
60	BBN	201	244	238	1.21	1.19
61	RYF	208	254	239	1.22	1.15
62	DVS	190	226	216	1.19	1.14
64	JUH	197	237	228	1.2	1.16
68	HRT	195	234	223	1.2	1.14
70	JUH	203	247	235	1.21	1.15
71	BBN	208	254	240	1.22	1.16
72	BLY	207	253	239	1.22	1.15
73	RYF	206	253	240	1.23	1.17
74	JUH	211	259	246	1.23	1.17
75	DIG	204	255	249	1.25	1.22
76	JUH	204	248	238	1.22	1.17
77	LAD	208	257	248	1.24	1.19
78	ABT	205	251	242	1.22	1.18
80	BWY	203	248	242	1.22	1.19
81	HZM	207	255	249	1.24	1.21
83	BUD	207	255	250	1.23	1.21
84	HZM	208	255	250	1.23	1.2
87	NPA	197	246	243	1.25	1.23
88	FAL	198	248	244	1.25	1.23
89	JUH	183	227	218	1.24	1.19
91	HZM	193	242	238	1.25	1.23
93	DON	193	241	239	1.25	1.24
94	HRT	206	257	250	1.25	1.22
97	FAL	208	254	248	1.22	1.19
98	HZM	217	267	262	1.23	1.21
99	CUL	230	285	279	1.24	1.22
101	FAL	208	253	247	1.22	1.19
102	WHW	211	258	253	1.22	1.2
103	ABT	214	264	257	1.23	1.2
104	HZM	218	269	263	1.23	1.21
105	CTE	228	283	278	1.24	1.22
107	ALC	205	255	249	1.24	1.21
108	HZM	218	269	262	1.24	1.2
109	PRV	220	273	267	1.24	1.21
110	CTE	235	293	289	1.25	1.23
112	ALC	225	279	273	1.24	1.21
130	DVS	170	201	195	1.18	1.14
132	CTE	178	215	208	1.21	1.17
133	BBN	201	247	239	1.22	1.19
135	DVS	199	242	235	1.22	1.18
144	BBN	168	207	194	1.23	1.15
170	HUB	170	212	196	1.25	1.16
171	HUB	174	214	199	1.23	1.15
172	KTH	179	216	201	1.21	1.12
173	CUL	180	217	202	1.21	1.12
176	HRT	183	209	197	1.14	1.08
177	HRT	183	219	206	1.2	1.13
178	HPE	197	235	226	1.19	1.15
180	KNZ	188	224	215	1.19	1.14
181	COS	182	217	208	1.19	1.14
182	ATO	199	239	231	1.2	1.16
185	UCS	199	237	228	1.19	1.15
189	CUL	184	211	200	1.15	1.09
192	COA	183	215	202	1.18	1.11
193	MLA	185	220	207	1.19	1.12
194	MLA	195	229	219	1.17	1.12
196	LNN	211	255	248	1.21	1.18
197	COA	204	242	232	1.18	1.14
198	COA	190	222	211	1.17	1.11
201	HRT	179	218	202	1.21	1.13
211	ZOR	179	211	203	1.18	1.13
212	ABC	178	208	201	1.17	1.13
215	ABC	180	212	204	1.18	1.13
218	KNZ	184	213	207	1.16	1.12
221	EGL	177	205	199	1.16	1.13
224	ABC	178	205	200	1.15	1.12
227	TNW	183	211	205	1.15	1.12
231	ABC	188	218	213	1.16	1.13
232	MLA	179	203	199	1.13	1.11
233	KNZ	179	203	199	1.14	1.11
236	ABC	181	209	204	1.16	1.13
240	KNZ	184	212	207	1.15	1.13
246	GDI	182	212	207	1.16	1.13
248	GDI	185	215	211	1.16	1.14
250	ABC	194	229	226	1.18	1.16
252	UCS	197	235	228	1.19	1.16
253	COD	203	243	236	1.2	1.16
254	PIB	211	255	248	1.21	1.17
258	POK	230	273	270	1.19	1.18
259	RDW	214	256	249	1.2	1.17
261	NIT	212	255	249	1.2	1.17
264	COA	202	244	236	1.21	1.17
268	KNZ	195	230	224	1.18	1.15
271	FLU	223	266	263	1.2	1.18

Appendix D-VI.2b (Continued).

Poly.#	Soil	SN6	SN5	SN4	SN5/SN6	SN4/SN6
275	RDW	220	260	260	1.18	1.18
279	ABC	206	245	243	1.19	1.18
290	ABC	182	210	206	1.16	1.13
291	LCY	184	213	210	1.16	1.14
292	TMN	185	214	211	1.16	1.14
296	NIT	183	195	199	1.07	1.09
297	GOG	186	214	212	1.15	1.14
301	SDN	190	211	213	1.11	1.12
302	LCY	189	206	210	1.09	1.11
306	LCY	198	234	233	1.18	1.18
310	FRY	210	247	249	1.18	1.19
311	FRY	215	255	255	1.18	1.19
312	FRY	211	248	250	1.18	1.18
315	NTW	187	214	213	1.14	1.14
316	LCY	191	221	221	1.15	1.15
317	LCY	189	217	217	1.15	1.15
320	FRY	195	226	228	1.16	1.17
322	LCY	205	247	249	1.2	1.21
323	LCY	206	247	249	1.2	1.21
325	LCY	203	241	242	1.18	1.19
326	LCY	196	221	224	1.13	1.14
334	LCY	217	261	261	1.2	1.21
335	FRY	210	252	254	1.2	1.21
337	MGS	233	285	287	1.22	1.23
339	LFN	236	289	290	1.23	1.23
341	MGS	220	267	268	1.22	1.22
342	LFN	220	269	269	1.22	1.22
343	FRY	222	272	272	1.23	1.23
344	BSU	227	281	280	1.23	1.23
345	SDN	229	283	282	1.24	1.23
346	PHS	223	271	271	1.22	1.22
347	SDN	225	269	271	1.19	1.2
348	SDN	221	264	267	1.19	1.2
350	LFN	232	271	274	1.17	1.18
351	LFN	232	281	282	1.21	1.21
352	RDW	235	285	286	1.21	1.22
354	BVH	247	305	305	1.23	1.23
356	EOR	234	293	297	1.25	1.27
357	EOR	237	294	295	1.24	1.25
359	RED	234	292	296	1.25	1.27
360	EOR	235	292	295	1.25	1.26
362	EOR	230	282	283	1.23	1.23
363	EOR	230	280	281	1.22	1.22
364	EOR	246	302	307	1.23	1.24
365	HND	232	279	284	1.2	1.23
366	DCY	224	269	274	1.2	1.22
367	HND	225	272	277	1.21	1.23
370	HND	193	209	218	1.09	1.13
371	WWT	209	246	254	1.18	1.22
372	EOR	225	275	282	1.22	1.25
374	EOR	227	281	287	1.23	1.26
375	WWT	218	266	274	1.22	1.25
376	HND	207	247	257	1.19	1.24
378	HND	198	230	242	1.16	1.22
392	AGS	236	278	281	1.18	1.19
393	LIZ	260	313	313	1.2	1.2
396	AGS	252	298	297	1.18	1.18
401	MGS	250	297	299	1.19	1.19
403	CMO	266	316	318	1.19	1.19
404	AGS	272	329	330	1.21	1.21
405	CMO	251	298	300	1.19	1.2
408	AGS	252	294	297	1.17	1.18
409	AGS	258	300	300	1.16	1.17
410	UCS	256	300	301	1.17	1.18
411	COA	248	286	283	1.16	1.14
412	CMO	246	287	289	1.17	1.18
416	WKN	253	299	301	1.18	1.19
418	MMO	221	261	255	1.18	1.15
420	TBY	211	248	239	1.17	1.13
421	HND	202	230	241	1.13	1.19
422	HCH	194	217	227	1.12	1.17
423	LET	190	214	224	1.13	1.18
425	HND	197	224	244	1.14	1.24
426	MMO	238	279	276	1.17	1.16
428	HND	182	206	232	1.13	1.27
429	FLU	247	285	280	1.15	1.13
430	MCO	252	292	290	1.16	1.15
431	AGS	255	298	295	1.17	1.16
432	KVG	235	276	271	1.17	1.16
433	POK	226	266	261	1.18	1.16
435	BTN	216	258	252	1.19	1.17
437	POK	235	278	274	1.18	1.17
439	COA	253	295	295	1.17	1.16
440	COA	214	250	241	1.17	1.13
441	MMO	232	273	269	1.18	1.16
442	WTB	226	266	262	1.18	1.16
443	HND	205	236	250	1.15	1.22
444	MET	220	261	267	1.19	1.21
449	KUR	174	197	221	1.13	1.27
451	MET	163	188	226	1.15	1.38
452	LET	165	189	222	1.14	1.34
453	CHN	162	186	228	1.15	1.41
457	MAB	155	180	227	1.16	1.47
458	MAB	148	173	223	1.17	1.51
460	WDN	150	175	224	1.17	1.49
461	BVL	156	180	227	1.16	1.46
463	HND	160	186	232	1.16	1.45
466	HND	163	187	225	1.15	1.38
467	WWT	169	192	222	1.14	1.32
471	HUK	163	185	224	1.14	1.38
472	MAB	146	173	223	1.18	1.53
473	HND	158	181	226	1.15	1.43
474	MAB	151	176	224	1.16	1.49
475	BVL	150	173	224	1.15	1.49
476	MAB	147	173	222	1.18	1.51
478	CCL	155	175	225	1.13	1.46
480	HUK	165	185	222	1.12	1.34
481	YTW	167	185	222	1.11	1.33
484	WWT	186	212	236	1.14	1.27
486	YTW	173	195	229	1.13	1.32
487	HUK	146	172	213	1.18	1.46
489	HUK	164	191	225	1.16	1.37
494	LHD	201	234	245	1.16	1.22
496	MET	175	204	234	1.17	1.34
499	CVD	121	144	164	1.19	1.36
508	AGS	249	295	298	1.19	1.2
509	PHS	233	276	273	1.19	1.17
510	AGS	240	282	286	1.18	1.19
512	BVH	239	288	293	1.2	1.23
513	AGS	248	293	295	1.18	1.19

Appendix D-VI.2b (Continued).

Poly.#	Soil	SN6	SN5	SN4	SN5/SN6	SN4/SN6
514	PHS	234	287	290	1.23	1.24
515	BVH	229	285	289	1.24	1.26
516	BVH	231	285	285	1.23	1.23
517	FLU	235	288	288	1.22	1.22
518	MGS	232	282	279	1.22	1.21
519	NVR	254	301	300	1.19	1.18
520	AGS	243	290	288	1.19	1.19
521	POK	227	275	270	1.21	1.19
523	PED	225	278	274	1.24	1.22
524	FLU	224	275	268	1.23	1.2
531	GDB	230	274	281	1.19	1.22
532	HKR	207	242	252	1.17	1.22
533	HND	204	242	255	1.18	1.25
534	MET	214	259	269	1.21	1.26
536	HND	222	271	277	1.22	1.25
537	BVH	223	271	274	1.22	1.23
538	HND	226	278	286	1.23	1.26
539	PHS	224	270	273	1.21	1.22
540	KLM	220	262	264	1.19	1.2
543	EOR	231	285	295	1.23	1.28
545	IRM	231	286	294	1.24	1.27
547	DEL	229	284	290	1.24	1.27
548	BVH	227	282	285	1.24	1.26
549	FLU	226	282	282	1.24	1.24
551	FLU	224	279	278	1.24	1.24
553	ATL	224	280	276	1.25	1.23
554	ATL	221	286	292	1.29	1.32
555	CYG	226	281	275	1.24	1.22
558	DEL	229	296	310	1.29	1.35
559	ATL	189	264	251	1.4	1.33
561	ATL	198	263	256	1.33	1.3
562	BGH	209	280	283	1.34	1.35
563	BSK	222	280	277	1.26	1.25
564	LET	173	234	240	1.36	1.39
565	DEL	231	296	311	1.28	1.35
566	DEL	219	284	301	1.3	1.38
567	BSK	219	276	286	1.26	1.31
568	DEL	231	286	297	1.24	1.28
569	IRM	225	281	288	1.25	1.28
570	HAN	222	276	288	1.24	1.29
571	HAN	214	263	274	1.23	1.28
572	DVG	183	254	253	1.39	1.38
574	LET	211	263	274	1.25	1.3
575	WWT	194	242	261	1.25	1.34
576	DMH	207	256	274	1.24	1.33
577	BZR	183	249	246	1.36	1.34
578	HAN	199	247	271	1.24	1.37
579	LET	191	237	257	1.24	1.35
581	HKR	189	222	244	1.17	1.29
582	HAN	206	252	269	1.22	1.3
583	HAN	199	241	260	1.21	1.31
584	DMH	219	271	282	1.23	1.29
589	HAN	201	246	266	1.22	1.32
590	CHN	139	165	221	1.19	1.59
591	BVL	144	172	225	1.19	1.57
592	FMT	146	176	232	1.2	1.59
593	CVD	145	174	230	1.21	1.59
595	ATP	137	168	247	1.23	1.81
596	FMT	160	202	261	1.26	1.64

Poly.#	Soil	SN6	SN5	SN4	SN5/SN6	SN4/SN6
598	FMT	162	205	262	1.27	1.62
599	MAB	158	191	245	1.21	1.55
600	CVD	165	203	255	1.23	1.54
601	MAB	147	177	221	1.2	1.51
602	MAB	154	184	232	1.2	1.51
603	MAB	164	199	242	1.21	1.47
605	HDY	158	192	229	1.22	1.45
606	CVD	139	168	195	1.21	1.41
607	CVD	146	178	206	1.22	1.41
608	MCT	159	196	232	1.23	1.46
609	TIY	156	193	221	1.24	1.41
610	BVL	163	199	233	1.22	1.43
611	HJK	165	204	237	1.23	1.43
613	CCL	169	211	255	1.25	1.5
615	CVD	170	210	247	1.24	1.45
616	CHN	173	214	257	1.24	1.49
617	FMT	175	218	265	1.24	1.51
618	CHN	174	218	266	1.25	1.52
619	FMT	174	220	268	1.27	1.54
620	MAB	174	225	270	1.29	1.56
621	TTH	178	230	266	1.29	1.49
622	TTH	178	232	268	1.3	1.51
623	ZRB	176	232	269	1.32	1.53
624	THA	181	240	266	1.32	1.47
626	SIL	164	222	281	1.36	1.72
627	MAB	167	222	278	1.33	1.66
628	BVL	171	224	275	1.31	1.61
629	SIL	170	224	277	1.32	1.63
631	MAB	178	226	274	1.27	1.54
632	MAB	179	225	276	1.26	1.54
633	MAB	177	225	268	1.27	1.52
634	MAB	177	226	274	1.28	1.55
635	MAB	178	226	273	1.27	1.53
637	MSN	177	225	268	1.27	1.52
638	ZRB	178	226	273	1.27	1.54
639	PUR	168	227	247	1.35	1.47
641	MAB	176	223	263	1.27	1.5
642	MAB	176	220	262	1.25	1.49
643	CHN	173	220	252	1.27	1.46
645	DLB	171	237	243	1.39	1.42
648	CFD	160	191	225	1.2	1.41
649	BVL	176	217	261	1.23	1.48
650	MAB	175	216	256	1.23	1.46
651	RDM	182	226	258	1.24	1.42
653	LET	183	230	249	1.25	1.36
654	PUY	174	217	258	1.25	1.48
655	DEL	198	260	274	1.31	1.38
656	PUY	181	236	248	1.31	1.37
657	LET	169	226	237	1.34	1.4
658	CMY	154	211	215	1.38	1.4
659	DEL	198	269	276	1.36	1.39
660	CVD	166	206	245	1.24	1.48
661	RDM	177	220	254	1.25	1.44
663	LET	166	220	234	1.32	1.41
664	RDM	174	222	244	1.27	1.4
666	PUR	157	212	230	1.35	1.47
667	LET	173	234	247	1.35	1.43
669	LOB	195	255	245	1.3	1.26
671	PHS	214	271	265	1.27	1.24

Appendix D-VI.2b (Continued).

Poly.#	Soil	SN6	SN5	SN4	SN5/SN6	SN4/SN6
672	PED	219	275	270	1.26	1.23
673	MMO	216	270	264	1.25	1.22
675	BTN	214	266	258	1.24	1.21
676	CYG	220	273	266	1.24	1.21
677	BEN	217	271	265	1.25	1.22
680	PNC	176	231	222	1.31	1.26
681	CYG	199	254	247	1.28	1.24
682	BEN	192	245	236	1.27	1.23
683	HUB	199	245	235	1.23	1.18
684	CAR	177	229	220	1.29	1.24
686	LOB	187	244	235	1.31	1.26
689	CAR	169	221	209	1.31	1.23
690	RMY	200	252	243	1.26	1.22
691	HUB	181	229	217	1.26	1.2
692	BTN	195	242	233	1.25	1.2
693	RMY	217	267	260	1.23	1.2
694	HUB	208	254	245	1.22	1.18
695	BTN	207	248	240	1.2	1.16
696	BTN	204	244	234	1.2	1.15
698	MYW	190	230	216	1.21	1.14
699	HUB	199	237	226	1.19	1.14
702	CVL	218	257	251	1.18	1.15
703	HGV	203	240	230	1.18	1.14
705	MCO	192	225	215	1.17	1.12
708	MLA	190	225	213	1.19	1.12
709	COA	190	225	212	1.18	1.12
710	COA	208	245	236	1.18	1.13
711	COA	196	231	220	1.18	1.12
715	KVG	203	239	228	1.17	1.12

Appendix D-VI.2c: Fallow-winter wheat rotation yields (g/m^2) averaged by Alberta Soil Landscape polygones for historical (1x; SN6) and doubled (2x; SN4 and SN5) atmospheric CO_2 concentrations.

Poly.#	Soil	SN6	SN5	SN4	SN5/SN6	SN4/SN6
2	FAL	204	397	256	1.94	1.25
3	DON	209	340	265	1.63	1.27
4	HZM	209	303	283	1.45	1.35
5	DON	210	288	288	1.37	1.37
6	ESH	213	295	273	1.38	1.28
7	COS	207	371	260	1.79	1.25
9	BBN	220	304	266	1.38	1.22
10	BBN	222	283	263	1.28	1.19
11	ESH	221	290	274	1.31	1.24
13	HZM	217	301	266	1.39	1.23
14	COS	226	291	264	1.29	1.17
15	ABT	224	289	264	1.29	1.18
19	HZM	224	288	264	1.28	1.18
20	LAD	220	284	262	1.29	1.19
22	COS	216	295	267	1.36	1.23
27	DON	204	284	270	1.39	1.32
28	HZM	210	355	261	1.69	1.24
32	HRT	220	273	258	1.24	1.17
33	HRT	219	276	259	1.26	1.18
36	COS	215	271	263	1.26	1.23
47	DON	215	278	273	1.29	1.27
48	DON	216	277	264	1.28	1.22
49	TAG	217	276	262	1.27	1.2
51	SAD	219	279	256	1.27	1.17
52	VVW	219	279	259	1.27	1.18
53	TAG	219	279	260	1.27	1.19
54	ESH	219	278	256	1.27	1.17
56	ZBR	216	272	266	1.26	1.23
59	FAL	217	274	283	1.26	1.31
60	BBN	219	268	291	1.22	1.33
61	RYF	218	282	267	1.29	1.22
62	DVS	203	264	273	1.3	1.34
64	JUH	211	267	278	1.26	1.32
68	HRT	208	269	273	1.29	1.31
70	JUH	216	287	283	1.33	1.31
71	BBN	219	287	275	1.31	1.25
72	BLY	218	283	269	1.3	1.23
73	RYF	220	298	284	1.35	1.29
74	JUH	224	307	295	1.37	1.31
75	DIG	226	298	264	1.32	1.17
76	JUH	218	288	281	1.32	1.29
77	LAD	225	301	277	1.34	1.23
78	ABT	221	290	277	1.32	1.25
80	BWY	218	290	267	1.33	1.22
81	HZM	225	293	265	1.3	1.18
83	BUD	224	289	263	1.29	1.18
84	HZM	223	287	263	1.29	1.18
87	NPA	220	291	253	1.32	1.15
88	FAL	221	286	254	1.29	1.15
89	JUH	208	377	253	1.82	1.22
91	HZM	216	338	240	1.57	1.11
93	DON	218	282	253	1.29	1.16
94	HRT	227	300	263	1.32	1.16
97	FAL	222	270	285	1.21	1.28
98	HZM	228	271	275	1.19	1.21
99	CUL	237	266	288	1.12	1.22
101	FAL	221	280	272	1.27	1.24
102	WHW	224	285	269	1.27	1.2
103	ABT	227	271	261	1.2	1.15
104	HZM	230	271	266	1.18	1.16
105	CTE	238	275	282	1.16	1.18
107	ALC	223	288	259	1.29	1.16
108	HZM	229	258	258	1.13	1.13
109	PRV	231	263	266	1.14	1.15
110	CTE	244	275	289	1.13	1.18
112	ALC	235	267	269	1.14	1.14
130	DVS	171	197	202	1.15	1.18
132	CTE	187	218	220	1.16	1.17
133	BBN	223	300	289	1.34	1.29
135	DVS	221	287	286	1.3	1.3
144	BBN	222	320	300	1.44	1.35
170	HUB	223	309	370	1.39	1.66
171	HUB	211	342	352	1.62	1.66
172	KTH	211	343	282	1.63	1.34
173	CUL	210	353	274	1.68	1.31
176	HRT	206	247	280	1.2	1.36
177	HRT	211	327	336	1.55	1.6
178	HPE	219	369	296	1.69	1.35
180	KNZ	212	359	310	1.69	1.46
181	COS	207	363	308	1.75	1.49
182	ATO	222	380	300	1.71	1.35
185	UCS	221	354	293	1.6	1.32
189	CUL	206	258	284	1.25	1.38
192	COA	209	308	290	1.47	1.39
193	MLA	210	355	306	1.69	1.46
194	MLA	216	311	287	1.44	1.33
196	LNN	232	402	289	1.73	1.24
197	COA	223	320	284	1.43	1.27
198	COA	213	303	296	1.42	1.39
201	HRT	209	373	270	1.78	1.29
211	ZOR	203	359	303	1.77	1.49
212	ABC	200	349	313	1.74	1.56
215	ABC	202	348	303	1.72	1.5
218	KNZ	196	304	271	1.55	1.38
221	EGL	196	353	301	1.8	1.54
224	ABC	194	341	298	1.75	1.53
227	TNW	193	296	272	1.53	1.41
231	ABC	198	297	275	1.5	1.39
232	MLA	187	276	251	1.47	1.34
233	KNZ	189	292	260	1.54	1.37
236	ABC	199	329	251	1.65	1.26
240	KNZ	197	307	270	1.56	1.37
246	GDI	203	330	292	1.63	1.44
248	GDI	206	337	354	1.63	1.71
250	ABC	214	352	334	1.64	1.56
252	UCS	217	374	297	1.72	1.37
253	COD	222	375	300	1.69	1.35
254	PIB	231	385	293	1.67	1.27
258	POK	243	318	300	1.31	1.24
259	RDW	229	339	308	1.48	1.35
261	NIT	226	337	321	1.49	1.42
264	COA	215	343	333	1.59	1.55
268	KNZ	207	322	302	1.55	1.46
271	FLU	236	328	320	1.39	1.35

Appendix D-VI.2c (Continued).

Poly.#	Soil	SN6	SN5	SN4	SN5/SN6	SN4/SN6
275	RDW	238	327	318	1.38	1.34
279	ABC	227	354	329	1.56	1.45
290	ABC	203	333	360	1.64	1.77
291	LCY	204	345	384	1.7	1.89
292	TMN	203	320	398	1.57	1.96
296	NIT	198	274	310	1.38	1.56
297	GOG	206	331	364	1.61	1.77
301	SDN	207	297	314	1.43	1.51
302	LCY	205	271	300	1.32	1.46
306	LCY	220	359	330	1.64	1.5
310	FRY	234	297	299	1.27	1.28
311	FRY	237	331	317	1.4	1.34
312	FRY	236	314	305	1.33	1.3
315	NTW	205	266	368	1.3	1.8
316	LCY	209	265	358	1.27	1.7
317	LCY	207	301	355	1.45	1.71
320	FRY	213	294	323	1.38	1.52
322	LCY	223	327	357	1.47	1.61
323	LCY	224	320	348	1.43	1.56
325	LCY	222	309	331	1.39	1.49
326	LCY	213	282	306	1.32	1.43
334	LCY	240	304	299	1.26	1.24
335	FRY	228	323	348	1.41	1.52
337	MGS	250	299	309	1.2	1.24
339	LFN	252	297	307	1.18	1.22
341	MGS	238	312	324	1.31	1.36
342	LFN	241	311	312	1.29	1.29
343	FRY	243	310	304	1.27	1.25
344	BSU	245	301	304	1.23	1.24
345	SDN	245	299	302	1.22	1.23
346	PHS	244	303	298	1.24	1.22
347	SDN	248	287	285	1.16	1.15
348	SDN	245	290	289	1.18	1.18
350	LFN	254	291	270	1.14	1.06
351	LFN	250	295	289	1.18	1.16
352	RDW	251	294	285	1.17	1.13
354	BVH	263	285	287	1.09	1.09
356	EOR	249	323	278	1.3	1.11
357	EOR	252	296	287	1.17	1.14
359	RED	248	278	287	1.12	1.16
360	EOR	249	282	290	1.13	1.17
362	EOR	246	262	279	1.07	1.14
363	EOR	243	255	273	1.05	1.12
364	EOR	256	265	270	1.04	1.06
365	HND	242	256	259	1.06	1.07
366	DCY	235	254	257	1.08	1.09
367	HND	237	256	260	1.08	1.1
370	HND	198	216	211	1.09	1.06
371	WWT	219	252	236	1.15	1.08
372	EOR	237	266	263	1.12	1.11
374	EOR	241	304	267	1.26	1.11
375	WWT	231	294	253	1.27	1.09
376	HND	220	267	236	1.21	1.07
378	HND	210	245	219	1.17	1.04
392	AGS	255	297	296	1.16	1.16
393	LIZ	271	321	325	1.19	1.2
396	AGS	263	299	299	1.14	1.14
401	MGS	261	307	306	1.18	1.17
403	CMO	276	306	313	1.11	1.13

Poly.#	Soil	SN6	SN5	SN4	SN5/SN6	SN4/SN6
404	AGS	282	319	326	1.13	1.16
405	CMO	266	302	304	1.13	1.14
408	AGS	266	285	286	1.07	1.07
409	AGS	270	277	287	1.03	1.06
410	UCS	268	291	295	1.09	1.1
411	COA	259	283	280	1.1	1.08
412	CMO	260	267	269	1.03	1.04
416	WKN	263	299	300	1.13	1.14
418	MMO	235	292	277	1.24	1.18
420	TBY	226	270	257	1.2	1.14
421	HND	208	246	227	1.18	1.1
422	HCH	200	231	218	1.16	1.09
423	LET	198	225	213	1.13	1.08
425	HND	200	285	230	1.43	1.15
426	MMO	251	283	282	1.13	1.13
428	HND	185	237	245	1.28	1.33
429	FLU	257	279	276	1.08	1.07
430	MCO	263	277	282	1.05	1.07
431	AGS	267	276	289	1.03	1.08
432	KVG	248	268	280	1.08	1.13
433	POK	240	266	275	1.11	1.15
435	BTN	231	264	287	1.14	1.24
437	POK	249	269	286	1.08	1.15
439	COA	265	285	288	1.08	1.09
440	COA	228	244	250	1.07	1.1
441	MMO	245	278	277	1.14	1.13
442	WTB	242	268	270	1.11	1.12
443	HND	210	267	232	1.27	1.11
444	MET	226	240	241	1.06	1.07
449	KUR	180	218	241	1.21	1.34
451	MET	168	206	252	1.22	1.5
452	LET	171	211	253	1.23	1.48
453	CHN	166	201	250	1.21	1.51
457	MAB	158	189	245	1.2	1.55
458	MAB	149	175	239	1.17	1.6
460	WDN	152	179	242	1.18	1.59
461	BVL	158	188	249	1.19	1.57
463	HND	164	199	247	1.22	1.5
466	HND	168	206	254	1.23	1.51
467	WWT	175	214	251	1.23	1.44
471	HUK	166	197	261	1.18	1.57
472	MAB	145	172	252	1.19	1.73
473	HND	161	189	260	1.17	1.61
474	MAB	152	178	255	1.17	1.67
475	BVL	152	174	267	1.14	1.76
476	MAB	146	172	266	1.18	1.83
478	CCL	158	176	275	1.11	1.74
480	HUK	166	186	274	1.12	1.65
481	YTW	167	184	278	1.1	1.67
484	WWT	185	217	254	1.17	1.37
486	YTW	171	195	266	1.14	1.56
487	HUK	145	175	248	1.21	1.71
489	HUK	158	197	248	1.25	1.57
494	LHD	203	227	234	1.12	1.15
496	MET	164	215	245	1.31	1.5
499	CVD	126	148	177	1.17	1.4
508	AGS	262	269	275	1.03	1.05
509	PHS	246	269	286	1.09	1.16
510	AGS	253	254	258	1	1.02

Appendix D-VI.2c (Continued).

Poly.#	Soil	SN6	SN5	SN4	SN5/SN6	SN4/SN6
512	BVH	251	265	262	1.06	1.05
513	AGS	260	265	272	1.02	1.05
514	PHS	246	266	257	1.08	1.05
515	BVH	238	249	245	1.04	1.03
516	BVH	244	272	261	1.12	1.07
517	FLU	251	290	272	1.16	1.08
518	MGS	246	271	270	1.1	1.1
519	NVR	267	279	286	1.05	1.07
520	AGS	257	274	282	1.07	1.1
521	POK	242	266	278	1.1	1.15
523	PED	239	265	260	1.11	1.09
524	FLU	240	259	266	1.08	1.11
531	GDB	238	242	246	1.02	1.03
532	HKR	211	234	235	1.11	1.12
533	HND	201	222	247	1.11	1.23
534	MET	210	231	247	1.1	1.18
536	HND	219	238	244	1.09	1.11
537	BVH	229	239	238	1.04	1.04
538	HND	223	246	250	1.11	1.12
539	PHS	231	239	237	1.03	1.03
540	KLM	226	232	232	1.02	1.02
543	EOR	228	253	254	1.11	1.12
545	IRM	233	251	250	1.08	1.07
547	DEL	234	258	256	1.1	1.1
548	BVH	237	251	247	1.06	1.04
549	FLU	239	258	253	1.08	1.06
551	FLU	238	262	252	1.1	1.06
553	ATL	239	252	246	1.05	1.03
554	ATL	275	263	259	0.96	0.94
555	CYG	238	271	254	1.14	1.07
558	DEL	289	267	261	0.93	0.9
559	ATL	244	252	247	1.03	1.01
561	ATL	254	271	269	1.07	1.06
562	BGH	254	264	256	1.04	1
563	BSK	246	250	246	1.01	1
564	LET	200	227	235	1.13	1.17
565	DEL	283	270	263	0.95	0.93
566	DEL	233	275	266	1.18	1.14
567	BSK	240	251	248	1.05	1.03
568	DEL	229	261	261	1.14	1.14
569	IRM	234	255	253	1.09	1.08
570	HAN	220	251	250	1.14	1.14
571	HAN	208	233	248	1.12	1.19
572	DVG	208	241	258	1.16	1.24
574	LET	215	241	237	1.12	1.1
575	WWT	199	224	228	1.13	1.15
576	DMH	203	235	239	1.16	1.18
577	BZR	202	235	246	1.17	1.22
578	HAN	194	228	239	1.18	1.23
579	LET	191	219	224	1.15	1.18
581	HKR	181	215	249	1.18	1.37
582	HAN	198	231	248	1.17	1.25
583	HAN	192	224	246	1.17	1.29
584	DMH	213	241	249	1.13	1.17
589	HAN	193	230	246	1.19	1.28
590	CHN	140	161	231	1.15	1.65
591	BVL	142	169	243	1.19	1.71
592	FMT	144	174	243	1.21	1.69
593	CVD	142	170	247	1.2	1.74
595	ATP	137	155	245	1.13	1.78
596	FMT	159	196	245	1.23	1.54
598	FMT	162	199	245	1.23	1.51
599	MAB	149	186	233	1.25	1.57
600	CVD	162	201	238	1.24	1.47
601	MAB	143	182	243	1.27	1.7
602	MAB	145	187	236	1.29	1.63
603	MAB	184	222	228	1.21	1.24
605	HDY	162	227	242	1.41	1.5
606	CVD	141	189	213	1.34	1.52
607	CVD	148	181	207	1.23	1.4
608	MCT	162	199	220	1.23	1.36
609	TIY	151	247	258	1.63	1.71
610	BVL	198	238	232	1.2	1.17
611	HUK	169	225	237	1.33	1.4
613	CCL	171	203	224	1.19	1.31
615	CVD	234	228	223	0.97	0.96
616	CHN	214	223	230	1.04	1.08
617	FMT	183	218	240	1.19	1.31
618	CHN	175	214	241	1.23	1.38
619	FMT	174	215	243	1.23	1.39
620	MAB	180	215	238	1.19	1.32
621	TTH	190	217	235	1.14	1.23
622	TTH	191	217	234	1.14	1.22
623	ZRB	191	216	232	1.13	1.21
624	THA	202	218	228	1.08	1.13
626	SIL	168	211	238	1.25	1.41
627	MAB	173	212	237	1.23	1.37
628	BVL	178	215	238	1.2	1.33
629	SIL	175	214	238	1.22	1.36
631	MAB	179	218	241	1.22	1.35
632	MAB	192	217	243	1.13	1.27
633	MAB	205	218	240	1.06	1.17
634	MAB	182	218	239	1.2	1.32
635	MAB	189	219	240	1.16	1.27
637	MSN	204	218	240	1.07	1.18
638	ZRB	191	218	240	1.14	1.26
639	PUR	204	220	227	1.08	1.12
641	MAB	222	219	234	0.99	1.05
642	MAB	237	221	228	0.93	0.96
643	CHN	247	221	227	0.9	0.92
645	DLB	204	229	227	1.12	1.11
648	CFD	226	240	212	1.06	0.94
649	BVL	263	217	234	0.83	0.89
650	MAB	227	219	230	0.96	1.01
651	RDM	192	215	226	1.12	1.18
653	LET	221	217	225	0.98	1.02
654	PUY	176	206	226	1.16	1.28
655	DEL	217	250	247	1.15	1.14
656	PUY	220	225	232	1.02	1.05
657	LET	209	222	233	1.06	1.11
658	CMY	185	213	223	1.15	1.2
659	DEL	221	248	247	1.12	1.12
660	CVD	170	205	224	1.21	1.32
661	RDM	209	216	228	1.03	1.09
663	LET	210	218	228	1.04	1.08
664	RDM	217	217	227	1	1.05
666	PUR	191	206	212	1.08	1.11
667	LET	228	226	231	0.99	1.01

Appendix D-VI.2c (Continued).

Poly.#	Soil	SN6	SN5	SN4	SN5/SN6	SN4/SN6
669	LOB	249	285	283	1.15	1.14
671	PHS	240	265	259	1.1	1.08
672	PED	238	268	257	1.13	1.08
673	MMO	234	275	262	1.17	1.12
675	BTN	231	266	269	1.15	1.17
676	CYG	237	261	265	1.1	1.12
677	BEN	233	272	262	1.17	1.13
680	PNC	217	294	296	1.35	1.36
681	CYG	230	281	277	1.22	1.21
682	BEN	220	280	284	1.28	1.29
683	HUB	212	255	288	1.2	1.36
684	CAR	210	289	296	1.38	1.41
686	LOB	237	290	290	1.22	1.23
689	CAR	191	292	306	1.53	1.61
690	RMY	219	272	278	1.24	1.27
691	HUB	195	274	297	1.41	1.52
692	BTN	207	268	284	1.29	1.37
693	RMY	233	260	269	1.12	1.16
694	HUB	222	258	284	1.16	1.28
695	BTN	221	256	292	1.16	1.32
696	BTN	217	252	288	1.16	1.32
698	MYW	204	249	298	1.22	1.46
699	HUB	212	259	278	1.22	1.31
702	CVL	234	268	272	1.15	1.16
703	HGV	217	273	269	1.26	1.24
705	MCO	202	260	238	1.29	1.18
708	MLA	208	305	291	1.47	1.4
709	COA	212	323	312	1.53	1.47
710	COA	224	278	275	1.24	1.23
711	COA	215	300	294	1.39	1.37
715	KVG	221	286	273	1.29	1.23

Appendix D-VI.2d: Fallow-corn rotation yields (g/m^2) averaged by Alberta Soil Landscape polygones for historical (1x; SN6) and doubled (2x; SN4 and SN5) atmospheric CO_2 concentrations. 0 represents areas without sufficient heat for corn to growth under current climate.

Poly.#	Soil	SN6	SN5	SN4	SN5/SN6	SN4/SN6
4	HZM	0	665	698	0	0
5	DON	0	661	694	0	0
9	BBN	0	665	697	0	0
10	BBN	0	648	684	0	0
11	ESH	0	647	684	0	0
13	HZM	0	666	694	0	0
14	COS	0	665	697	0	0
15	ABT	0	661	691	0	0
19	HZM	0	659	689	0	0
20	LAD	0	649	682	0	0
22	COS	0	650	677	0	0
27	DON	0	661	690	0	0
31	DVS	0	654	685	0	0
33	HRT	0	650	682	0	0
34	KNZ	0	649	682	0	0
47	DON	0	679	711	0	0
48	DON	0	653	688	0	0
49	TAG	0	649	684	0	0
51	SAD	0	635	674	0	0
52	VVW	0	646	681	0	0
53	TAG	0	651	683	0	0
54	ESH	0	631	672	0	0
56	ZBR	0	686	718	0	0
61	RYF	0	641	680	0	0
71	BBN	0	645	682	0	0
72	BLY	0	643	681	0	0
144	BBN	0	777	801	0	0
170	HUB	0	827	837	0	0
171	HUB	0	814	835	0	0
172	KTH	0	800	827	0	0
173	CUL	0	810	833	0	0
176	HRT	0	653	735	0	0
177	HRT	0	765	809	0	0
178	HPE	0	760	815	0	0
180	KNZ	0	766	816	0	0
182	ATO	0	757	815	0	0
185	UCS	0	737	800	0	0
189	CUL	0	663	742	0	0
192	COA	0	735	787	0	0
193	MLA	0	782	817	0	0
194	MLA	0	712	780	0	0
196	LNN	0	756	818	0	0
197	COA	0	731	798	0	0
198	COA	0	720	780	0	0
201	HRT	0	829	846	0	0
215	ABC	0	771	821	0	0
216	KNZ	0	745	814	0	0
227	TNW	0	731	806	0	0
231	ABC	0	713	797	0	0
248	GDI	0	657	751	0	0
252	UCS	0	757	819	0	0
253	COD	0	752	818	0	0
254	PIB	0	749	816	0	0
258	POK	0	703	793	0	0
259	RDW	0	726	807	0	0
261	NIT	0	723	809	0	0
264	COA	0	734	817	0	0
270	MPV	0	710	798	0	0
271	FLU	0	690	782	0	0
275	RDW	0	641	740	0	0
279	ABC	0	650	746	0	0
301	SDN	0	639	735	0	0
302	LCY	0	633	728	0	0
306	LCY	0	650	745	0	0
310	FRY	0	588	690	0	0
311	FRY	0	614	716	0	0
312	FRY	0	575	683	0	0
325	LCY	0	627	719	0	0
326	LCY	0	634	727	0	0
334	LCY	0	617	712	0	0
341	MGS	0	628	719	0	0
343	FRY	0	644	732	0	0
344	BSU	0	627	717	0	0
345	SDN	0	625	715	0	0
346	PHS	0	624	716	0	0
347	SDN	0	572	674	0	0
348	SDN	0	578	680	0	0
350	LFN	0	572	670	0	0
351	LFN	0	607	699	0	0
352	RDW	0	613	702	0	0
356	EOR	0	569	670	0	0
357	EOR	0	600	696	0	0
359	RED	0	602	701	0	0
360	EOR	0	610	705	0	0
362	EOR	0	600	704	0	0
363	EOR	0	593	698	0	0
364	EOR	0	612	705	0	0
365	HND	0	575	673	0	0
366	DCY	0	557	656	0	0
367	HND	0	565	665	0	0
370	HND	0	423	517	0	0
371	WWT	0	504	606	0	0
372	EOR	0	562	662	0	0
374	EOR	0	554	657	0	0
392	AGS	0	586	693	0	0
396	AGS	0	669	769	0	0
400	MGS	0	674	775	0	0
403	CMO	0	652	755	0	0
404	AGS	0	662	762	0	0
405	CMO	0	616	720	0	0
408	AGS	0	611	717	0	0
409	AGS	0	644	744	0	0
410	UCS	0	645	749	0	0
411	COA	0	648	756	0	0
412	CMO	0	614	714	0	0
416	WKN	0	679	782	0	0
418	MMO	0	699	786	0	0
420	TBY	0	697	782	0	0
421	HND	0	470	586	0	0
422	HCH	0	440	564	0	0
425	HND	0	455	613	0	0
426	MMO	0	694	784	0	0

Appendix D-VI.2d (Continued).

Poly.#	Soil	SN6	SN5	SN4	SN5/SN6	SN4/SN6
428	HND	0	396	557	0	0
429	FLU	0	652	758	0	0
430	MCO	0	657	756	0	0
431	AGS	0	677	766	0	0
432	KVG	0	705	787	0	0
433	POK	0	731	802	0	0
435	BTN	0	748	813	0	0
437	POK	0	713	790	0	0
439	COA	0	645	750	0	0
440	COA	0	696	781	0	0
441	MMO	0	693	783	0	0
442	WTB	0	733	804	0	0
443	HND	0	485	618	0	0
444	MET	0	538	646	0	0
450	LET	0	337	491	0	0
451	MET	294	317	484	1.08	1.64
453	CHN	296	309	485	1.04	1.64
457	MAB	284	290	477	1.02	1.68
458	MAB	256	271	465	1.06	1.81
460	WDN	267	277	469	1.04	1.75
461	BVL	288	293	480	1.02	1.66
463	HND	304	300	482	0.99	1.58
466	HND	0	319	485	0	0
468	HND	0	339	497	0	0
471	HUK	291	319	492	1.1	1.69
472	MAB	257	275	472	1.07	1.84
473	HND	291	301	489	1.03	1.68
474	MAB	272	285	479	1.05	1.76
475	BVL	270	284	484	1.05	1.79
476	MAB	263	283	480	1.07	1.82
478	CCL	282	293	494	1.04	1.75
480	HUK	0	329	502	0	0
481	YTW	0	332	503	0	0
484	WWT	0	407	563	0	0
486	YTW	0	354	526	0	0
487	HUK	266	283	458	1.06	1.72
489	HUK	294	323	500	1.1	1.7
494	LHD	0	475	605	0	0
496	MET	0	350	529	0	0
499	CVD	0	229	311	0	0
508	AGS	0	647	743	0	0
509	PHS	0	717	793	0	0
510	AGS	0	612	711	0	0
512	BVH	0	634	736	0	0
513	AGS	0	639	736	0	0
514	PHS	0	649	750	0	0
515	BVH	0	636	740	0	0
516	BVH	0	678	771	0	0
517	FLU	0	683	779	0	0
518	MGS	0	707	789	0	0
519	NVR	0	675	765	0	0
520	AGS	0	693	778	0	0
521	POK	0	726	800	0	0
523	PED	0	720	795	0	0
524	FLU	0	742	811	0	0
531	GDB	0	587	695	0	0
532	HKR	0	503	627	0	0
533	HND	0	470	610	0	0
534	MET	0	498	627	0	0
536	HND	0	543	657	0	0
537	BVH	0	596	701	0	0
538	HND	0	566	677	0	0
539	PHS	0	599	702	0	0
540	KLM	0	580	685	0	0
543	EOR	0	588	695	0	0
545	IRM	0	616	719	0	0
547	DEL	0	629	724	0	0
548	BVH	0	649	744	0	0
549	FLU	0	678	768	0	0
551	FLU	0	688	769	0	0
553	ATL	0	675	754	0	0
554	ATL	0	643	737	0	0
555	CYG	0	736	803	0	0
558	DEL	0	621	727	0	0
559	ATL	0	653	725	0	0
561	ATL	0	670	747	0	0
562	BGH	0	623	717	0	0
563	BSK	0	667	748	0	0
564	LET	359	457	569	1.27	1.58
565	DEL	0	616	723	0	0
566	DEL	0	560	672	0	0
567	BSK	0	585	691	0	0
568	DEL	0	592	694	0	0
569	IRM	0	604	702	0	0
570	HAN	0	555	667	0	0
571	HAN	377	485	618	1.29	1.64
572	DVG	0	506	582	0	0
574	LET	0	538	652	0	0
575	WWT	364	475	607	1.31	1.67
576	DMH	383	487	629	1.27	1.64
577	BZR	0	489	578	0	0
578	HAN	396	432	606	1.09	1.53
579	LET	369	461	602	1.25	1.63
581	HKR	340	399	564	1.18	1.66
582	HAN	0	443	596	0	0
583	HAN	378	428	583	1.13	1.54
584	DMH	386	508	638	1.31	1.65
589	HAN	0	421	583	0	0
590	CHN	228	249	455	1.1	2
591	BVL	246	269	475	1.1	1.93
592	FMT	253	281	498	1.11	1.97
593	CVD	248	277	494	1.12	1.99
595	ATP	215	253	534	1.18	2.49
596	FMT	275	335	565	1.22	2.06
598	FMT	281	344	568	1.23	2.02
599	MAB	275	317	535	1.15	1.95
600	CVD	281	335	550	1.2	1.95
601	MAB	269	290	478	1.08	1.78
602	MAB	276	306	506	1.11	1.83
603	MAB	298	339	531	1.14	1.78
605	HDY	300	328	506	1.09	1.69
606	CVD	268	278	405	1.04	1.51
607	CVD	289	298	441	1.03	1.53
608	MCT	331	340	527	1.03	1.59
609	TIY	311	332	488	1.07	1.57
610	BVL	330	354	529	1.07	1.6
611	HUK	336	351	528	1.04	1.57
613	CCL	366	370	599	1.01	1.64
615	CVD	340	380	567	1.12	1.66
616	CHN	326	372	579	1.14	1.77

Appendix D-VI.2d (Continued).

Poly.#	Soil	SN6	SN5	SN4	SN5/SN6	SN4/SN6
617	FMT	311	366	572	1.18	1.84
618	CHN	299	367	571	1.23	1.91
619	FMT	306	381	580	1.25	1.9
620	MAB	297	409	588	1.38	1.98
621	TTH	0	463	613	0	0
622	TTH	299	465	613	1.55	2.05
623	ZRB	288	472	612	1.64	2.13
624	THA	0	535	642	0	0
626	SIL	0	361	552	0	0
627	MAB	281	371	562	1.32	2
628	BVL	293	378	571	1.29	1.95
629	SIL	289	375	568	1.3	1.97
631	MAB	314	377	583	1.2	1.86
632	MAB	321	384	605	1.2	1.88
633	MAB	329	401	601	1.22	1.82
634	MAB	310	379	582	1.22	1.88
635	MAB	318	384	591	1.21	1.86
637	MSN	327	404	603	1.23	1.84
638	ZRB	320	384	594	1.2	1.86
639	PUR	335	432	570	1.29	1.7
641	MAB	340	400	597	1.18	1.75
642	MAB	345	386	603	1.12	1.75
643	CHN	358	404	583	1.13	1.63
645	DLB	0	469	572	0	0
648	CFD	326	355	518	1.09	1.59
649	BVL	369	395	614	1.07	1.66
650	MAB	364	382	587	1.05	1.61
651	RDM	370	395	571	1.07	1.54
653	LET	360	431	557	1.2	1.55
654	PUY	371	383	605	1.03	1.63
655	DEL	0	502	609	0	0
656	PUY	0	443	546	0	0
657	LET	359	421	535	1.17	1.49
658	CMY	0	367	454	0	0
659	DEL	0	516	597	0	0
660	CVD	350	358	564	1.02	1.61
661	RDM	367	389	572	1.06	1.56
663	LET	0	399	521	0	0
664	RDM	0	404	545	0	0
666	PUR	0	432	569	0	0
667	LET	365	450	570	1.23	1.56
669	LOB	0	707	776	0	0
671	PHS	0	701	774	0	0
672	PED	0	715	786	0	0
673	MMO	0	736	802	0	0
675	BTN	0	749	813	0	0
676	CYG	0	744	812	0	0
677	BEN	0	740	806	0	0
680	PNC	0	751	809	0	0
681	CYG	0	735	799	0	0
682	BEN	0	757	816	0	0
683	HUB	0	788	837	0	0
684	CAR	0	770	823	0	0
686	LOB	0	727	791	0	0
689	CAR	0	781	827	0	0
690	RMY	0	762	821	0	0
691	HUB	0	803	845	0	0
692	BTN	0	792	841	0	0
693	RMY	0	754	818	0	0
694	HUB	0	768	824	0	0
695	BTN	0	767	823	0	0
696	BTN	0	774	824	0	0
698	MYW	0	797	835	0	0
699	HUB	0	768	818	0	0
702	CVL	0	745	809	0	0
703	HGV	0	749	805	0	0
705	MCO	0	746	798	0	0
708	MLA	0	770	811	0	0
709	COA	0	774	811	0	0
710	COA	0	737	800	0	0
711	COA	0	753	803	0	0
715	KVG	0	717	788	0	0

Appendix D-VI.3a: Irrigated canola yields (g/m^2) averaged by Alberta Soil Landscape polygones for historical (1x; SN6) and doubled (2x; SN4 and SN5) atmospheric CO_2 concentrations.

Poly.#	Soil	SN6	SN5	SN4	SN5/SN6	SN4/SN6
2	FAL	249	375	372	1.5	1.49
3	DON	256	371	368	1.45	1.44
4	HZM	261	372	367	1.42	1.4
5	DON	267	369	364	1.38	1.36
6	ESH	261	368	367	1.41	1.4
7	COS	251	374	370	1.49	1.47
9	BBN	253	368	363	1.45	1.43
10	BBN	264	361	357	1.36	1.35
11	ESH	274	358	355	1.31	1.3
13	HZM	246	370	366	1.5	1.49
14	COS	249	367	362	1.47	1.45
15	ABT	248	368	363	1.48	1.46
19	HZM	250	367	363	1.47	1.45
20	LAD	259	365	362	1.41	1.4
22	COS	250	370	367	1.48	1.47
27	DON	235	374	372	1.59	1.58
28	HZM	252	372	368	1.48	1.46
32	HRT	265	369	367	1.39	1.39
33	HRT	263	368	366	1.4	1.39
36	COS	259	368	367	1.42	1.41
47	DON	269	358	357	1.33	1.33
48	DON	269	360	358	1.34	1.33
49	TAG	267	362	360	1.35	1.35
51	SAD	271	357	354	1.32	1.31
52	VVW	265	364	361	1.37	1.36
53	TAG	261	368	365	1.41	1.4
54	ESH	275	354	352	1.29	1.28
56	ZBR	266	355	355	1.33	1.33
59	FAL	281	349	352	1.24	1.25
60	BBN	284	346	351	1.22	1.24
61	RYF	277	353	352	1.27	1.27
62	DVS	286	339	342	1.18	1.19
64	JUH	284	343	346	1.21	1.22
68	HRT	283	344	346	1.22	1.22
70	JUH	285	350	349	1.23	1.23
71	BBN	279	354	353	1.27	1.26
72	BLY	278	353	352	1.27	1.27
73	RYF	276	360	358	1.31	1.3
74	JUH	285	357	355	1.25	1.24
75	DIG	268	366	364	1.37	1.36
76	JUH	284	349	350	1.23	1.23
77	LAD	277	361	359	1.3	1.3
78	ABT	280	354	353	1.26	1.26
80	BWY	276	350	351	1.27	1.27
81	HZM	274	359	358	1.31	1.31
83	BUD	274	354	354	1.29	1.29
84	HZM	274	352	353	1.28	1.29
87	NPA	257	364	367	1.42	1.43
88	FAL	258	366	368	1.42	1.43
89	JUH	251	371	369	1.48	1.47
91	HZM	250	360	362	1.44	1.45
93	DON	253	367	371	1.45	1.46
94	HRT	269	366	364	1.36	1.35
97	FAL	281	348	352	1.24	1.25
98	HZM	274	353	354	1.29	1.29
99	CUL	277	353	356	1.28	1.29
101	FAL	278	349	350	1.25	1.26
102	WHW	276	350	351	1.27	1.27
103	ABT	275	350	351	1.27	1.28
104	HZM	276	350	352	1.27	1.27
105	CTE	277	355	356	1.28	1.28
107	ALC	266	358	359	1.35	1.35
108	HZM	274	348	349	1.27	1.27
109	PRV	275	350	352	1.28	1.28
110	CTE	278	358	358	1.29	1.29
112	ALC	276	352	353	1.27	1.28
130	DVS	264	318	322	1.21	1.22
132	CTE	244	329	332	1.35	1.36
133	BBN	273	361	361	1.32	1.32
135	DVS	277	355	357	1.28	1.29
144	BBN	231	388	382	1.67	1.65
170	HUB	223	401	376	1.8	1.69
171	HUB	244	395	385	1.62	1.58
172	KTH	265	397	384	1.5	1.45
173	CUL	266	398	384	1.5	1.44
176	HRT	298	380	383	1.28	1.29
177	HRT	275	392	390	1.42	1.42
178	HPE	304	391	393	1.28	1.29
180	KNZ	291	390	390	1.34	1.34
181	COS	287	389	389	1.36	1.36
182	ATO	303	390	393	1.29	1.3
185	UCS	306	389	392	1.27	1.28
189	CUL	298	381	384	1.28	1.29
192	COA	284	391	385	1.37	1.35
193	MLA	284	398	389	1.4	1.37
194	MLA	307	388	390	1.26	1.27
196	LNN	315	391	396	1.24	1.26
197	COA	318	392	395	1.23	1.24
198	COA	305	390	391	1.28	1.28
201	HRT	261	400	383	1.53	1.47
211	ZOR	289	386	387	1.33	1.34
212	ABC	291	381	384	1.31	1.32
215	ABC	292	383	386	1.31	1.32
218	KNZ	304	374	380	1.23	1.25
221	EGL	296	374	379	1.26	1.28
224	ABC	298	373	378	1.25	1.27
227	TNW	306	371	378	1.21	1.24
231	ABC	308	370	378	1.2	1.23
232	MLA	303	365	373	1.2	1.23
233	KNZ	301	368	374	1.22	1.24
236	ABC	296	372	376	1.26	1.27
240	KNZ	303	370	376	1.22	1.24
246	GDI	295	370	376	1.25	1.27
248	GDI	296	367	375	1.24	1.27
250	ABC	299	367	376	1.22	1.26
252	UCS	305	387	391	1.27	1.28
253	COD	311	387	392	1.24	1.26
254	PIB	316	389	394	1.23	1.25
258	POK	326	378	378	1.16	1.19
259	RDW	321	383	391	1.19	1.22
261	NIT	322	382	391	1.19	1.21
264	COA	320	382	392	1.2	1.23
268	KNZ	313	376	385	1.2	1.23
271	FLU	318	373	382	1.17	1.2
275	RDW	307	362	372	1.18	1.21
279	ABC	302	364	374	1.2	1.24
290	ABC	294	368	376	1.25	1.28
291	LCY	292	368	376	1.26	1.29

Appendix D-VI.3a (Continued).

Poly.#	Soil	SN6	SN5	SN4	SN5/SN6	SN4/SN6
292	TMN	290	366	372	1.26	1.28
296	NIT	295	349	357	1.18	1.21
297	GOG	294	363	371	1.24	1.26
301	SDN	297	353	362	1.19	1.22
302	LCY	298	348	357	1.17	1.2
306	LCY	299	363	373	1.21	1.25
310	FRY	303	353	361	1.16	1.19
311	FRY	304	359	369	1.18	1.21
312	FRY	301	354	363	1.17	1.21
315	NTW	292	360	365	1.23	1.25
316	LCY	294	360	364	1.22	1.24
317	LCY	294	360	366	1.22	1.24
320	FRY	298	357	364	1.2	1.22
322	LCY	300	354	358	1.18	1.19
323	LCY	301	354	359	1.18	1.19
325	LCY	301	355	361	1.18	1.2
326	LCY	300	351	358	1.17	1.19
334	LCY	308	357	365	1.16	1.18
335	FRY	303	353	358	1.17	1.18
337	MGS	303	345	352	1.14	1.16
339	LFN	304	344	351	1.13	1.16
341	MGS	305	352	359	1.15	1.17
342	LFN	309	357	363	1.16	1.18
343	FRY	311	360	366	1.15	1.18
344	BSU	310	355	362	1.14	1.17
345	SDN	311	355	363	1.14	1.16
346	PHS	310	357	364	1.15	1.17
347	SDN	306	350	358	1.14	1.17
348	SDN	307	352	360	1.15	1.17
350	LFN	305	347	356	1.14	1.17
351	LFN	309	352	360	1.14	1.16
352	RDW	310	352	360	1.13	1.16
354	BVH	304	341	349	1.12	1.15
356	EOR	303	344	351	1.14	1.16
357	EOR	307	347	354	1.13	1.15
359	RED	313	355	361	1.13	1.15
360	EOR	313	354	360	1.13	1.15
362	EOR	315	356	362	1.13	1.15
363	EOR	316	357	364	1.13	1.15
364	EOR	318	355	367	1.12	1.15
365	HND	316	354	364	1.12	1.15
366	DCY	314	354	361	1.13	1.15
367	HND	314	354	362	1.13	1.15
370	HND	310	347	354	1.12	1.14
371	WWT	307	348	356	1.13	1.16
372	EOR	312	352	359	1.13	1.15
374	EOR	305	347	353	1.14	1.16
375	WWT	302	345	352	1.14	1.16
376	HND	303	345	353	1.14	1.17
378	HND	302	346	354	1.15	1.17
392	AGS	309	354	363	1.15	1.18
393	LIZ	318	366	374	1.15	1.18
396	AGS	326	371	380	1.14	1.16
401	MGS	330	370	380	1.12	1.15
403	CMO	320	363	373	1.13	1.16
404	AGS	318	364	372	1.14	1.17
405	CMO	314	357	367	1.14	1.17
408	AGS	317	356	367	1.12	1.16
409	AGS	322	365	376	1.13	1.16
410	UCS	324	364	375	1.13	1.16

Poly.#	Soil	SN6	SN5	SN4	SN5/SN6	SN4/SN6
411	COA	329	371	382	1.13	1.16
412	CMO	318	357	368	1.12	1.16
416	WKN	332	371	381	1.12	1.15
418	MMO	327	383	391	1.17	1.2
420	TBY	327	388	395	1.19	1.21
421	HND	311	350	359	1.13	1.15
422	HCH	304	344	351	1.13	1.15
423	LET	298	339	347	1.14	1.16
425	HND	307	353	361	1.15	1.18
426	MMO	331	379	387	1.15	1.17
428	HND	305	347	354	1.14	1.16
429	FLU	330	373	384	1.13	1.16
430	MCO	326	371	381	1.14	1.17
431	AGS	324	373	382	1.15	1.18
432	KVG	326	380	388	1.17	1.19
433	POK	327	386	391	1.18	1.2
435	BTN	323	389	393	1.2	1.22
437	POK	323	381	387	1.18	1.2
439	COA	325	366	377	1.13	1.16
440	COA	331	389	395	1.18	1.2
441	MMO	331	381	389	1.15	1.18
442	WTB	333	387	393	1.16	1.18
443	HND	310	353	362	1.14	1.17
444	MET	313	352	363	1.12	1.16
449	KUR	298	339	344	1.14	1.16
451	MET	295	337	341	1.14	1.15
452	LET	296	338	342	1.14	1.15
453	CHN	295	336	340	1.14	1.15
457	MAB	291	333	336	1.14	1.15
458	MAB	288	328	330	1.14	1.15
460	WDN	289	330	332	1.14	1.15
461	BVL	292	334	337	1.14	1.15
463	HND	293	335	339	1.15	1.16
466	HND	296	337	341	1.14	1.15
467	WWT	298	339	344	1.14	1.16
471	HUK	299	339	344	1.14	1.15
472	MAB	291	329	333	1.13	1.14
473	HND	296	337	342	1.14	1.15
474	MAB	293	333	337	1.13	1.15
475	BVL	295	335	339	1.13	1.15
476	MAB	295	333	338	1.13	1.14
478	CCL	298	338	343	1.13	1.15
480	HUK	306	344	349	1.12	1.14
481	YTW	308	346	350	1.12	1.14
484	WWT	310	349	356	1.13	1.15
486	YTW	307	345	351	1.12	1.14
487	HUK	293	331	337	1.13	1.15
489	HUK	300	338	345	1.13	1.15
494	LHD	310	350	360	1.13	1.16
496	MET	303	340	348	1.12	1.15
499	CVD	277	314	322	1.13	1.16
508	AGS	317	365	375	1.15	1.18
509	PHS	319	381	387	1.19	1.21
510	AGS	317	358	368	1.13	1.16
512	BVH	314	363	373	1.16	1.19
513	AGS	318	364	374	1.15	1.18
514	PHS	314	368	377	1.17	1.2
515	BVH	312	367	376	1.17	1.2
516	BVH	312	373	382	1.2	1.22
517	FLU	315	374	383	1.19	1.22

Appendix D-VI.3a (Continued).

Poly.#	Soil	SN6	SN5	SN4	SN5/SN6	SN4/SN6
518	MGS	313	379	386	1.21	1.23
519	NVR	319	371	380	1.16	1.19
520	AGS	318	376	383	1.18	1.21
521	POK	315	383	389	1.21	1.23
523	PED	304	381	387	1.25	1.27
524	FLU	311	387	391	1.24	1.26
531	GDB	312	355	365	1.14	1.17
532	HKR	310	351	360	1.13	1.16
533	HND	311	350	358	1.12	1.15
534	MET	310	349	358	1.13	1.16
536	HND	309	350	360	1.13	1.16
537	BVH	311	358	367	1.15	1.18
538	HND	308	352	360	1.14	1.17
539	PHS	312	358	367	1.15	1.18
540	KLM	311	353	364	1.14	1.17
543	EOR	308	354	362	1.15	1.18
545	IRM	308	361	369	1.17	1.2
547	DEL	301	362	370	1.2	1.23
548	BVH	305	369	376	1.21	1.23
549	FLU	308	374	381	1.21	1.24
551	FLU	300	376	382	1.25	1.27
553	ATL	293	376	381	1.28	1.3
554	ATL	265	383	388	1.44	1.46
555	CYG	306	383	388	1.25	1.27
558	DEL	277	390	394	1.41	1.42
559	ATL	187	358	361	1.92	1.93
561	ATL	214	367	374	1.71	1.74
562	BGH	239	372	375	1.55	1.57
563	BSK	284	378	383	1.33	1.35
564	LET	288	344	363	1.19	1.26
565	DEL	283	391	395	1.38	1.4
566	DEL	276	381	385	1.38	1.39
567	BSK	289	371	376	1.28	1.3
568	DEL	300	355	362	1.18	1.2
569	IRM	294	363	369	1.24	1.26
570	HAN	301	353	359	1.17	1.19
571	HAN	308	346	356	1.13	1.16
572	DVG	229	392	393	1.71	1.71
574	LET	296	355	359	1.2	1.21
575	WWT	299	355	363	1.19	1.21
576	DMH	302	347	355	1.15	1.17
577	BZR	253	390	393	1.54	1.55
578	HAN	304	341	354	1.12	1.16
579	LET	301	351	359	1.17	1.19
581	HKR	309	345	354	1.12	1.15
582	HAN	306	342	353	1.12	1.15
583	HAN	306	342	352	1.12	1.15
584	DMH	307	347	356	1.13	1.16
589	HAN	305	339	351	1.11	1.15
590	CHN	284	323	324	1.14	1.14
591	BVL	289	326	330	1.13	1.14
592	FMT	291	328	332	1.13	1.14
593	CVD	291	329	332	1.13	1.14
595	ATP	292	332	335	1.14	1.15
596	FMT	293	334	339	1.14	1.16
598	FMT	292	334	339	1.14	1.16
599	MAB	290	327	332	1.13	1.14
600	CVD	292	329	334	1.13	1.14
601	MAB	292	328	334	1.13	1.14
602	MAB	290	327	332	1.13	1.14

Poly.#	Soil	SN6	SN5	SN4	SN5/SN6	SN4/SN6
603	MAB	297	329	334	1.11	1.12
605	HDY	296	331	337	1.12	1.14
606	CVD	287	323	331	1.13	1.15
607	CVD	290	326	336	1.13	1.16
608	MCT	297	334	345	1.12	1.16
609	TIY	297	335	342	1.13	1.15
610	BVL	301	334	342	1.11	1.13
611	HUK	298	336	346	1.13	1.16
613	CCL	303	340	353	1.12	1.16
615	CVD	302	333	341	1.1	1.13
616	CHN	299	331	338	1.11	1.13
617	FMT	296	332	336	1.12	1.13
618	CHN	294	332	336	1.13	1.15
619	FMT	293	336	340	1.14	1.16
620	MAB	290	342	346	1.18	1.2
621	TTH	285	349	356	1.22	1.25
622	TTH	285	350	357	1.23	1.25
623	ZRB	283	352	358	1.24	1.26
624	THA	277	360	369	1.3	1.33
626	SIL	291	338	336	1.16	1.16
627	MAB	292	339	340	1.16	1.16
628	BVL	293	340	342	1.16	1.17
629	SIL	292	339	341	1.16	1.17
631	MAB	296	339	343	1.15	1.16
632	MAB	298	341	348	1.14	1.16
633	MAB	297	343	351	1.15	1.18
634	MAB	296	341	345	1.15	1.17
635	MAB	297	341	347	1.15	1.17
637	MSN	297	343	352	1.16	1.19
638	ZRB	297	341	347	1.15	1.17
639	PUR	288	354	364	1.23	1.26
641	MAB	299	338	347	1.13	1.16
642	MAB	300	330	340	1.1	1.13
643	CHN	303	336	344	1.11	1.13
645	DLB	281	365	376	1.3	1.34
648	CFD	304	333	338	1.09	1.11
649	BVL	307	333	341	1.09	1.11
650	MAB	304	335	345	1.1	1.14
651	RDM	297	343	356	1.16	1.2
653	LET	289	351	361	1.21	1.25
654	PUY	303	342	354	1.13	1.17
655	DEL	266	370	376	1.39	1.41
656	PUY	274	359	368	1.31	1.34
657	LET	282	351	363	1.24	1.28
658	CMY	289	348	360	1.2	1.24
659	DEL	249	382	388	1.53	1.55
660	CVD	300	338	349	1.12	1.16
661	RDM	299	339	351	1.13	1.17
663	LET	291	347	358	1.19	1.23
664	RDM	292	346	357	1.19	1.22
666	PUR	288	354	364	1.23	1.26
667	LET	291	353	363	1.21	1.24
669	LOB	219	372	380	1.7	1.74
671	PHS	271	378	383	1.39	1.41
672	PED	285	380	385	1.33	1.35
673	MMO	282	382	386	1.35	1.37
675	BTN	287	386	390	1.34	1.35
676	CYG	300	386	391	1.29	1.3
677	BEN	289	383	387	1.32	1.34
680	PNC	192	381	382	1.98	1.99

Appendix D-VI.3a (Continued).

Poly.#	Soil	SN6	SN5	SN4	SN5/SN6	SN4/SN6
681	CYG	240	381	385	1.58	1.6
682	BEN	238	385	387	1.62	1.62
683	HUB	285	393	394	1.38	1.38
684	CAR	208	386	386	1.86	1.86
686	LOB	205	377	382	1.84	1.86
689	CAR	205	368	369	1.79	1.8
690	RMY	264	386	388	1.46	1.47
691	HUB	247	390	389	1.58	1.57
692	BTN	269	393	392	1.46	1.46
693	RMY	300	388	392	1.29	1.31
694	HUB	297	390	393	1.31	1.32
695	BTN	312	391	394	1.25	1.26
696	BTN	307	392	394	1.28	1.28
698	MYW	289	393	394	1.36	1.36
699	HUB	304	391	393	1.28	1.29
702	CVL	328	390	394	1.19	1.2
703	HGV	314	390	393	1.24	1.25
705	MCO	305	388	390	1.27	1.28
708	MLA	299	394	392	1.32	1.31
709	COA	309	398	397	1.29	1.28
710	COA	321	391	395	1.22	1.23
711	COA	315	395	397	1.25	1.26
715	KVG	321	392	396	1.22	1.23

Appendix D-VI.3b: Irrigated spring wheat yields (g/m^2) averaged by Alberta Soil Landscape polygones for historical (1x; SN6) and doubled (2x; SN4 and SN5) atmospheric CO_2 concentrations.

Poly.#	Soil	SN6	SN5	SN4	SN5/SN6	SN4/SN6
2	FAL	363	410	401	1.13	1.11
3	DON	366	412	403	1.13	1.1
4	HZM	367	414	403	1.13	1.1
5	DON	369	415	404	1.12	1.1
6	ESH	368	413	404	1.12	1.1
7	COS	364	413	403	1.13	1.11
9	BBN	367	424	409	1.15	1.11
10	BBN	369	425	412	1.15	1.12
11	ESH	370	422	411	1.14	1.11
13	HZM	365	424	409	1.16	1.12
14	COS	367	430	412	1.17	1.12
15	ABT	367	430	412	1.17	1.12
19	HZM	367	430	412	1.17	1.12
20	LAD	368	425	411	1.16	1.12
22	COS	367	425	409	1.16	1.11
27	DON	361	420	406	1.16	1.12
28	HZM	364	415	404	1.14	1.11
32	HRT	370	424	409	1.15	1.11
33	HRT	369	424	409	1.15	1.11
36	COS	368	422	408	1.15	1.11
47	DON	366	420	410	1.15	1.12
48	DON	368	422	410	1.15	1.12
49	TAG	368	423	410	1.15	1.11
51	SAD	369	424	413	1.15	1.12
52	VVW	369	424	411	1.15	1.11
53	TAG	369	424	410	1.15	1.11
54	ESH	369	423	413	1.14	1.12
56	ZBR	364	419	410	1.15	1.13
59	FAL	368	421	411	1.14	1.12
60	BBN	371	423	413	1.14	1.11
61	RYF	369	421	412	1.14	1.12
62	DVS	361	413	405	1.14	1.12
64	JUH	365	418	409	1.15	1.12
68	HRT	364	416	407	1.14	1.12
70	JUH	368	418	409	1.13	1.11
71	BBN	369	420	411	1.14	1.11
72	BLY	369	421	411	1.14	1.12
73	RYF	370	419	410	1.13	1.11
74	JUH	372	419	411	1.13	1.1
75	DIG	371	420	411	1.13	1.11
76	JUH	368	419	410	1.14	1.11
77	LAD	371	420	411	1.13	1.11
78	ABT	369	420	411	1.14	1.11
80	BWY	368	425	411	1.15	1.12
81	HZM	370	424	413	1.14	1.11
83	BUD	370	426	414	1.15	1.12
84	HZM	369	427	415	1.16	1.12
87	NPA	367	415	406	1.13	1.11
88	FAL	368	415	407	1.13	1.11
89	JUH	364	411	402	1.13	1.1
91	HZM	367	414	403	1.13	1.1
93	DON	367	412	403	1.12	1.1
94	HRT	372	421	412	1.13	1.11
97	FAL	370	425	417	1.15	1.13
98	HZM	367	426	423	1.16	1.15
99	CUL	372	432	430	1.16	1.16
101	FAL	368	425	415	1.16	1.13
102	WHW	369	429	416	1.16	1.13
103	ABT	369	430	421	1.16	1.14
104	HZM	370	432	424	1.17	1.14
105	CTE	373	435	430	1.17	1.15
107	ALC	368	422	413	1.14	1.12
108	HZM	369	431	425	1.17	1.15
109	PRV	369	431	426	1.17	1.15
110	CTE	374	437	435	1.17	1.16
112	ALC	372	435	429	1.17	1.15
130	DVS	340	383	383	1.12	1.13
132	CTE	343	396	394	1.16	1.15
133	BBN	367	424	416	1.15	1.13
135	DVS	368	422	413	1.15	1.12
144	BBN	351	415	405	1.18	1.16
170	HUB	349	418	406	1.2	1.16
171	HUB	360	417	406	1.16	1.13
172	KTH	368	419	405	1.14	1.1
173	CUL	369	419	405	1.13	1.1
176	HRT	373	419	405	1.12	1.09
177	HRT	370	419	408	1.13	1.1
178	HPE	379	424	410	1.12	1.08
180	KNZ	375	421	407	1.12	1.09
181	COS	373	418	405	1.12	1.09
182	ATO	380	425	411	1.12	1.08
185	UCS	380	425	411	1.12	1.08
189	CUL	374	419	406	1.12	1.08
192	COA	372	420	406	1.13	1.09
193	MLA	373	420	407	1.12	1.09
194	MLA	379	424	409	1.12	1.08
196	LNN	384	430	415	1.12	1.08
197	COA	384	427	411	1.11	1.07
198	COA	378	422	408	1.12	1.08
201	HRT	369	418	405	1.13	1.1
211	ZOR	373	416	403	1.11	1.08
212	ABC	374	414	402	1.11	1.07
215	ABC	374	416	403	1.11	1.08
218	KNZ	377	418	404	1.11	1.07
221	EGL	373	412	399	1.1	1.07
224	ABC	373	413	400	1.11	1.07
227	TNW	377	416	403	1.11	1.07
231	ABC	378	418	405	1.1	1.07
232	MLA	375	415	402	1.11	1.07
233	KNZ	375	414	402	1.11	1.07
236	ABC	374	411	401	1.1	1.07
240	KNZ	376	415	403	1.1	1.07
246	GDI	374	412	401	1.1	1.07
248	GDI	376	415	403	1.1	1.07
250	ABC	378	417	406	1.11	1.08
252	UCS	380	424	409	1.12	1.08
253	COD	382	426	411	1.11	1.08
254	PIB	385	430	414	1.12	1.08
258	POK	391	434	424	1.11	1.08
259	RDW	387	428	415	1.11	1.07
261	NIT	387	427	413	1.1	1.07
264	COA	384	422	407	1.1	1.06
268	KNZ	381	420	406	1.1	1.07
271	FLU	388	428	418	1.1	1.08

Appendix D-VI.3b (Continued).

Poly.#	Soil	SN6	SN5	SN4	SN5/SN6	SN4/SN6
275	RDW	383	424	418	1.11	1.09
279	ABC	380	420	411	1.11	1.08
290	ABC	375	413	401	1.1	1.07
291	LCY	373	413	403	1.11	1.08
292	TMN	371	413	404	1.11	1.09
296	NIT	370	415	408	1.12	1.1
297	GOG	373	415	405	1.11	1.09
301	SDN	373	417	409	1.12	1.1
302	LCY	372	417	411	1.12	1.11
306	LCY	377	419	408	1.11	1.08
310	FRY	376	419	417	1.11	1.11
311	FRY	380	420	415	1.11	1.09
312	FRY	376	416	413	1.1	1.1
315	NTW	371	414	406	1.12	1.09
316	LCY	372	416	408	1.12	1.09
317	LCY	372	416	407	1.12	1.09
320	FRY	374	419	411	1.12	1.1
322	LCY	376	423	414	1.12	1.1
323	LCY	376	422	415	1.12	1.1
325	LCY	376	422	415	1.12	1.1
326	LCY	374	420	414	1.12	1.11
334	LCY	380	426	423	1.12	1.11
335	FRY	377	424	417	1.12	1.11
337	MGS	377	422	423	1.12	1.12
339	LFN	377	422	424	1.12	1.12
341	MGS	379	426	422	1.12	1.11
342	LFN	381	429	425	1.13	1.12
343	FRY	382	431	427	1.13	1.12
344	BSU	383	430	428	1.12	1.12
345	SDN	384	431	429	1.12	1.12
346	PHS	382	429	426	1.12	1.12
347	SDN	379	422	423	1.11	1.12
348	SDN	379	422	422	1.11	1.11
350	LFN	379	421	423	1.11	1.12
351	LFN	383	428	427	1.12	1.12
352	RDW	384	430	429	1.12	1.12
354	BVH	377	421	427	1.12	1.13
356	EOR	376	425	429	1.13	1.14
357	EOR	380	427	430	1.12	1.13
359	RED	387	436	437	1.13	1.13
360	EOR	386	434	435	1.12	1.13
362	EOR	387	437	435	1.13	1.12
363	EOR	389	439	436	1.13	1.12
364	EOR	393	441	444	1.12	1.13
365	HND	389	438	438	1.12	1.12
366	DCY	387	436	435	1.12	1.12
367	HND	387	436	435	1.13	1.12
370	HND	381	424	421	1.11	1.11
371	WWT	381	428	426	1.12	1.12
372	EOR	385	434	435	1.13	1.13
374	EOR	378	428	430	1.13	1.14
375	WWT	376	425	425	1.13	1.13
376	HND	376	424	422	1.13	1.12
378	HND	377	424	419	1.12	1.11
392	AGS	384	424	424	1.11	1.11
393	LIZ	396	439	435	1.11	1.1
396	AGS	395	440	432	1.11	1.09
401	MGS	397	441	436	1.11	1.1
403	CMO	397	441	438	1.11	1.1
404	AGS	399	443	441	1.11	1.1
405	CMO	390	432	431	1.11	1.11
408	AGS	391	433	432	1.11	1.1
409	AGS	395	440	435	1.11	1.1
410	UCS	395	438	433	1.11	1.1
411	COA	393	437	427	1.11	1.08
412	CMO	391	436	432	1.12	1.1
416	WKN	398	442	437	1.11	1.1
418	MMO	389	433	418	1.11	1.08
420	TBY	386	430	412	1.11	1.07
421	HND	382	430	425	1.13	1.11
422	HCH	374	421	418	1.12	1.12
423	LET	368	414	413	1.12	1.12
425	HND	379	433	423	1.14	1.12
426	MMO	393	438	425	1.11	1.08
428	HND	373	423	417	1.14	1.12
429	FLU	393	438	426	1.11	1.08
430	MCO	394	440	431	1.12	1.09
431	AGS	395	442	434	1.12	1.1
432	KVG	391	438	424	1.12	1.08
433	POK	390	436	420	1.12	1.08
435	BTN	387	434	417	1.12	1.08
437	POK	391	438	426	1.12	1.09
439	COA	394	438	431	1.11	1.09
440	COA	387	432	413	1.12	1.07
441	MMO	392	436	423	1.11	1.08
442	WTB	392	437	420	1.12	1.07
443	HND	382	434	426	1.14	1.11
444	MET	386	436	431	1.13	1.12
449	KUR	365	411	412	1.13	1.13
451	MET	360	410	413	1.14	1.15
452	LET	363	409	412	1.13	1.13
453	CHN	358	411	413	1.15	1.15
457	MAB	353	407	410	1.15	1.16
458	MAB	349	399	401	1.14	1.15
460	WDN	350	402	404	1.15	1.15
461	BVL	354	408	411	1.15	1.16
463	HND	354	412	416	1.16	1.17
466	HND	361	410	413	1.14	1.14
467	WWT	365	411	412	1.13	1.13
471	HUK	363	413	412	1.14	1.14
472	MAB	353	402	405	1.14	1.15
473	HND	359	412	413	1.15	1.15
474	MAB	355	406	409	1.14	1.15
475	BVL	358	409	410	1.14	1.15
476	MAB	358	407	411	1.14	1.15
478	CCL	361	414	413	1.14	1.14
480	HUK	369	417	411	1.13	1.11
481	YTW	371	419	410	1.13	1.11
484	WWT	376	427	419	1.13	1.11
486	YTW	372	421	415	1.13	1.12
487	HUK	358	404	407	1.13	1.14
489	HUK	366	414	414	1.13	1.13
494	LHD	381	432	424	1.13	1.11
496	MET	371	419	419	1.13	1.13
499	CVD	344	380	386	1.1	1.12
508	AGS	393	444	436	1.13	1.11
509	PHS	390	438	425	1.12	1.09
510	AGS	391	440	433	1.13	1.11
512	BVH	391	445	434	1.14	1.11
513	AGS	393	443	436	1.13	1.11

Appendix D-VI.3b (Continued).

Poly.#	Soil	SN6	SN5	SN4	SN5/SN6	SN4/SN6
514	PHS	391	449	429	1.15	1.1
515	BVH	390	451	426	1.16	1.09
516	BVH	390	448	426	1.15	1.09
517	FLU	391	449	427	1.15	1.09
518	MGS	389	444	427	1.14	1.1
519	NVR	394	446	435	1.13	1.1
520	AGS	392	444	431	1.13	1.1
521	POK	389	440	424	1.13	1.09
523	PED	387	443	425	1.15	1.1
524	FLU	387	440	424	1.14	1.1
531	GDB	388	440	434	1.14	1.12
532	HKR	382	433	425	1.13	1.11
533	HND	381	432	426	1.13	1.12
534	MET	382	433	431	1.13	1.13
536	HND	384	435	431	1.13	1.12
537	BVH	387	442	427	1.14	1.1
538	HND	384	435	428	1.13	1.12
539	PHS	387	442	428	1.14	1.1
540	KLM	386	438	428	1.14	1.11
543	EOR	384	437	426	1.14	1.11
545	IRM	387	443	425	1.15	1.1
547	DEL	384	439	424	1.14	1.1
548	BVH	387	447	424	1.15	1.1
549	FLU	389	448	425	1.15	1.09
551	FLU	385	444	424	1.15	1.1
553	ATL	383	441	421	1.15	1.1
554	ATL	376	445	422	1.19	1.12
555	CYG	387	446	425	1.15	1.1
558	DEL	381	452	425	1.19	1.12
559	ATL	339	429	413	1.26	1.22
561	ATL	353	433	415	1.22	1.17
562	BGH	359	441	420	1.23	1.17
563	BSK	380	442	420	1.16	1.1
564	LET	381	430	417	1.13	1.09
565	DEL	384	452	426	1.18	1.11
566	DEL	381	447	426	1.17	1.12
567	BSK	380	439	421	1.15	1.11
568	DEL	381	432	423	1.13	1.11
569	IRM	381	436	422	1.14	1.11
570	HAN	380	430	420	1.13	1.11
571	HAN	381	431	432	1.13	1.13
572	DVG	363	436	418	1.2	1.15
574	LET	377	428	415	1.13	1.1
575	WWT	379	428	417	1.13	1.1
576	DMH	378	426	421	1.13	1.11
577	BZR	373	436	418	1.17	1.12
578	HAN	378	425	424	1.12	1.12
579	LET	378	426	416	1.13	1.1
581	HKR	376	425	422	1.13	1.12
582	HAN	378	426	427	1.13	1.13
583	HAN	377	425	425	1.13	1.13
584	DMH	381	431	430	1.13	1.13
589	HAN	376	423	425	1.12	1.13
590	CHN	344	391	393	1.14	1.14
591	BVL	350	397	401	1.14	1.15
592	FMT	352	401	406	1.14	1.15
593	CVD	352	401	406	1.14	1.15
595	ATP	353	406	412	1.15	1.17
596	FMT	355	408	415	1.15	1.17

Poly.#	Soil	SN6	SN5	SN4	SN5/SN6	SN4/SN6
598	FMT	356	408	414	1.15	1.17
599	MAB	351	400	408	1.14	1.16
600	CVD	354	399	406	1.13	1.15
601	MAB	355	401	407	1.13	1.15
602	MAB	353	401	408	1.13	1.16
603	MAB	360	397	403	1.1	1.12
605	HDY	362	403	408	1.11	1.13
606	CVD	354	393	398	1.11	1.12
607	CVD	359	400	404	1.11	1.12
608	MCT	369	413	415	1.12	1.12
609	TIY	366	407	411	1.11	1.12
610	BVL	372	408	412	1.1	1.11
611	HUK	371	411	416	1.11	1.12
613	CCL	378	424	424	1.12	1.12
615	CVD	376	412	414	1.1	1.1
616	CHN	369	409	413	1.11	1.12
617	FMT	360	405	409	1.12	1.14
618	CHN	357	403	408	1.13	1.14
619	FMT	358	409	414	1.14	1.16
620	MAB	360	419	420	1.16	1.17
621	TTH	366	424	421	1.16	1.15
622	TTH	366	427	423	1.17	1.16
623	ZRB	365	430	426	1.18	1.17
624	THA	371	438	427	1.18	1.15
626	SIL	349	419	426	1.2	1.22
627	MAB	354	420	425	1.19	1.2
628	BVL	360	421	426	1.17	1.18
629	SIL	357	421	426	1.18	1.19
631	MAB	367	421	425	1.15	1.16
632	MAB	377	430	431	1.14	1.14
633	MAB	380	430	427	1.13	1.13
634	MAB	368	425	428	1.15	1.16
635	MAB	373	427	428	1.14	1.15
637	MSN	380	431	427	1.13	1.12
638	ZRB	374	427	429	1.14	1.15
639	PUR	380	434	423	1.14	1.11
641	MAB	378	423	422	1.12	1.12
642	MAB	376	416	419	1.11	1.11
643	CHN	379	416	417	1.1	1.1
645	DLB	381	437	420	1.15	1.1
648	CFD	374	404	407	1.08	1.09
649	BVL	384	418	421	1.09	1.1
650	MAB	380	416	421	1.09	1.11
651	RDM	379	420	425	1.11	1.12
653	LET	379	427	421	1.13	1.11
654	PUY	378	426	425	1.13	1.12
655	DEL	372	437	422	1.17	1.13
656	PUY	375	430	419	1.15	1.12
657	LET	378	427	417	1.13	1.1
658	CMY	379	428	415	1.13	1.09
659	DEL	369	437	420	1.19	1.14
660	CVD	374	418	420	1.12	1.12
661	RDM	380	419	422	1.1	1.11
663	LET	380	426	418	1.12	1.1
664	RDM	379	424	420	1.12	1.11
666	PUR	380	434	422	1.14	1.11
667	LET	381	429	419	1.13	1.1
669	LOB	359	431	414	1.2	1.15
671	PHS	376	439	419	1.17	1.11

Appendix D-VI.3b (Continued).

Poly.#	Soil	SN6	SN5	SN4	SN5/SN6	SN4/SN6
672	PED	381	442	422	1.16	1.11
673	MMO	379	441	422	1.16	1.11
675	BTN	381	438	421	1.15	1.11
676	CYG	385	440	423	1.14	1.1
677	BEN	381	441	422	1.16	1.11
680	PNC	354	425	411	1.2	1.16
681	CYG	368	434	417	1.18	1.13
682	BEN	368	431	416	1.17	1.13
683	HUB	379	429	415	1.13	1.1
684	CAR	359	425	412	1.18	1.15
686	LOB	357	428	413	1.2	1.16
689	CAR	345	420	407	1.22	1.18
690	RMY	374	433	418	1.16	1.12
691	HUB	367	424	411	1.15	1.12
692	BTN	376	429	416	1.14	1.1
693	RMY	384	438	422	1.14	1.1
694	HUB	382	432	417	1.13	1.09
695	BTN	383	430	414	1.12	1.08
696	BTN	381	427	413	1.12	1.08
698	MYW	375	421	409	1.12	1.09
699	HUB	379	425	411	1.12	1.08
702	CVL	389	434	417	1.12	1.07
703	HGV	382	426	411	1.12	1.08
705	MCO	376	420	406	1.11	1.08
708	MLA	377	421	407	1.12	1.08
709	COA	380	421	408	1.11	1.07
710	COA	385	429	413	1.11	1.07
711	COA	382	424	409	1.11	1.07
715	KVG	384	427	410	1.11	1.07

Appendix D-VI.3c: Irrigated corn yields (g/m^2) averaged by Alberta Soil Landscape polygones for historical (1x; SN6) and doubled (2x; SN4 and SN5) atmospheric CO_2 concentrations. 0 represents areas without sufficient heat for corn to growth under current climate.

Poly.#	Soil	SN6	SN5	SN4	SN5/SN6	SN4/SN6
4	HZM	0	757	755	0	0
5	DON	0	755	753	0	0
9	BBN	0	753	750	0	0
10	BBN	0	747	743	0	0
11	ESH	0	750	747	0	0
13	HZM	0	764	764	0	0
14	COS	0	752	749	0	0
15	ABT	0	758	756	0	0
19	HZM	0	757	756	0	0
20	LAD	0	757	755	0	0
22	COS	0	766	768	0	0
27	DON	0	774	776	0	0
31	DVS	0	765	766	0	0
33	HRT	0	760	760	0	0
34	KNZ	0	762	763	0	0
47	DON	0	773	775	0	0
48	DON	0	759	758	0	0
49	TAG	0	758	756	0	0
51	SAD	0	747	742	0	0
52	VVW	0	755	753	0	0
53	TAG	0	760	760	0	0
54	ESH	0	745	739	0	0
56	ZBR	0	776	779	0	0
61	RYF	0	750	746	0	0
71	BBN	0	752	748	0	0
72	BLY	0	751	747	0	0
144	BBN	0	822	838	0	0
170	HUB	0	846	856	0	0
171	HUB	0	842	859	0	0
172	KTH	0	844	856	0	0
173	CUL	0	845	858	0	0
176	HRT	0	812	825	0	0
177	HRT	0	836	855	0	0
178	HPE	0	828	853	0	0
180	KNZ	0	832	855	0	0
182	ATO	0	827	853	0	0
185	UCS	0	824	847	0	0
189	CUL	0	814	828	0	0
192	COA	0	828	842	0	0
193	MLA	0	834	852	0	0
194	MLA	0	822	842	0	0
196	LNN	0	824	852	0	0
197	COA	0	824	849	0	0
198	COA	0	825	842	0	0
201	HRT	0	848	861	0	0
215	ABC	0	829	855	0	0
218	KNZ	0	819	850	0	0
227	TNW	0	812	846	0	0
231	ABC	0	805	841	0	0
248	GDI	0	783	814	0	0
252	UCS	0	824	853	0	0
253	COD	0	821	852	0	0
254	PIB	0	821	851	0	0
258	POK	0	803	837	0	0
259	RDW	0	811	845	0	0
261	NIT	0	808	845	0	0
264	COA	0	809	849	0	0
270	MPV	0	802	840	0	0
271	FLU	0	793	830	0	0
275	RDW	0	776	810	0	0
279	ABC	0	781	812	0	0
301	SDN	0	775	805	0	0
302	LCY	0	769	798	0	0
306	LCY	0	781	811	0	0
310	FRY	0	756	786	0	0
311	FRY	0	768	801	0	0
312	FRY	0	757	789	0	0
325	LCY	0	765	793	0	0
326	LCY	0	768	796	0	0
334	LCY	0	762	790	0	0
341	MGS	0	764	790	0	0
343	FRY	0	768	794	0	0
344	BSU	0	761	788	0	0
345	SDN	0	760	786	0	0
346	PHS	0	762	789	0	0
347	SDN	0	748	777	0	0
348	SDN	0	751	781	0	0
350	LFN	0	745	771	0	0
351	LFN	0	755	781	0	0
352	RDW	0	755	780	0	0
356	EOR	0	754	776	0	0
357	EOR	0	758	782	0	0
359	RED	0	760	780	0	0
360	EOR	0	760	782	0	0
362	EOR	0	756	779	0	0
363	EOR	0	753	778	0	0
364	EOR	0	747	776	0	0
365	HND	0	748	775	0	0
366	DCY	0	751	774	0	0
367	HND	0	753	775	0	0
370	HND	0	741	760	0	0
371	WWT	0	748	768	0	0
372	EOR	0	756	775	0	0
374	EOR	0	753	773	0	0
392	AGS	0	755	789	0	0
396	AGS	0	791	824	0	0
400	MGS	0	788	823	0	0
403	CMO	0	777	813	0	0
404	AGS	0	774	814	0	0
405	CMO	0	764	799	0	0
408	AGS	0	766	795	0	0
409	AGS	0	783	811	0	0
410	UCS	0	782	814	0	0
411	COA	0	795	822	0	0
412	CMO	0	766	794	0	0
416	WKN	0	792	826	0	0
418	MMO	0	811	840	0	0
420	TBY	0	817	844	0	0
421	HND	0	744	765	0	0
422	HCH	0	739	758	0	0
425	HND	0	744	764	0	0
426	MMO	0	807	836	0	0
428	HND	0	731	748	0	0
429	FLU	0	799	824	0	0

Appendix D-VI.3c (Continued).

Poly.#	Soil	SN6	SN5	SN4	SN5/SN6	SN4/SN6
430	MCO	0	793	820	0	0
431	AGS	0	796	823	0	0
432	KVG	0	809	835	0	0
433	POK	0	820	845	0	0
435	BTN	0	819	847	0	0
437	POK	0	807	834	0	0
439	COA	0	785	815	0	0
440	COA	0	819	845	0	0
441	MMO	0	808	837	0	0
442	WTB	0	824	850	0	0
443	HND	0	745	767	0	0
444	MET	0	742	767	0	0
450	LET	0	709	720	0	0
451	MET	661	695	710	1.05	1.07
453	CHN	661	688	705	1.04	1.07
457	MAB	658	673	692	1.02	1.05
458	MAB	655	659	677	1.01	1.03
460	WDN	656	664	682	1.01	1.04
461	BVL	659	677	696	1.03	1.06
463	HND	660	677	699	1.02	1.06
466	HND	0	698	712	0	0
468	HND	0	712	725	0	0
471	HUK	661	704	718	1.06	1.09
472	MAB	660	670	685	1.02	1.04
473	HND	661	692	708	1.05	1.07
474	MAB	660	679	695	1.03	1.05
475	BVL	662	688	702	1.04	1.06
476	MAB	666	686	698	1.03	1.05
478	CCL	662	699	713	1.06	1.08
480	HUK	0	721	735	0	0
481	YTW	0	727	740	0	0
484	WWT	0	734	750	0	0
486	YTW	0	724	738	0	0
487	HUK	662	686	698	1.04	1.05
489	HUK	664	703	717	1.06	1.08
494	LHD	0	738	757	0	0
496	MET	0	708	722	0	0
499	CVD	0	658	670	0	0
508	AGS	0	777	803	0	0
509	PHS	0	806	833	0	0
510	AGS	0	763	791	0	0
512	BVH	0	770	795	0	0
513	AGS	0	775	801	0	0
514	PHS	0	775	800	0	0
515	BVH	0	769	791	0	0
516	BVH	0	787	811	0	0
517	FLU	0	791	818	0	0
518	MGS	0	799	824	0	0
519	NVR	0	790	816	0	0
520	AGS	0	796	823	0	0
521	POK	0	807	834	0	0
523	PED	0	800	824	0	0
524	FLU	0	810	835	0	0
531	GDB	0	752	773	0	0
532	HKR	0	740	760	0	0
533	HND	0	737	752	0	0
534	MET	0	734	747	0	0
536	HND	0	738	752	0	0
537	BVH	0	755	774	0	0
538	HND	0	744	759	0	0

Poly.#	Soil	SN6	SN5	SN4	SN5/SN6	SN4/SN6
539	PHS	0	755	775	0	0
540	KLM	0	748	767	0	0
543	EOR	0	749	766	0	0
545	IRM	0	759	778	0	0
547	DEL	0	763	781	0	0
548	BVH	0	773	793	0	0
549	FLU	0	785	808	0	0
551	FLU	0	787	808	0	0
553	ATL	0	780	796	0	0
554	ATL	0	800	814	0	0
555	CYG	0	802	827	0	0
558	DEL	0	811	823	0	0
559	ATL	0	773	791	0	0
561	ATL	0	786	802	0	0
562	BGH	0	795	809	0	0
563	BSK	0	784	798	0	0
564	LET	687	756	760	1.1	1.11
565	DEL	0	808	820	0	0
566	DEL	0	790	804	0	0
567	BSK	0	774	787	0	0
568	DEL	0	750	765	0	0
569	IRM	0	762	776	0	0
570	HAN	0	746	760	0	0
571	HAN	676	727	740	1.08	1.1
572	DVG	0	818	825	0	0
574	LET	0	749	762	0	0
575	WWT	683	746	762	1.09	1.11
576	DMH	681	732	748	1.08	1.1
577	BZR	0	808	815	0	0
578	HAN	682	720	738	1.06	1.08
579	LET	684	739	755	1.08	1.1
581	HKR	671	725	739	1.08	1.1
582	HAN	0	721	734	0	0
583	HAN	676	720	734	1.06	1.09
584	DMH	677	731	744	1.08	1.1
589	HAN	0	715	729	0	0
590	CHN	650	641	659	0.99	1.01
591	BVL	657	659	674	1	1.03
592	FMT	659	665	678	1.01	1.03
593	CVD	660	665	679	1.01	1.03
595	ATP	655	658	675	1	1.03
596	FMT	663	667	678	1.01	1.02
598	FMT	664	668	678	1.01	1.02
599	MAB	656	666	677	1.02	1.03
600	CVD	657	664	675	1.01	1.03
601	MAB	664	677	689	1.02	1.04
602	MAB	660	673	684	1.02	1.04
603	MAB	665	675	683	1.01	1.03
605	HDY	672	688	699	1.02	1.04
606	CVD	660	677	690	1.02	1.04
607	CVD	663	683	701	1.03	1.06
608	MCT	678	699	722	1.03	1.06
609	TIY	681	702	716	1.03	1.05
610	BVL	684	702	714	1.03	1.04
611	HUK	683	705	720	1.03	1.05
613	CCL	689	711	740	1.03	1.07
615	CVD	680	700	713	1.03	1.05
616	CHN	671	685	701	1.02	1.04
617	FMT	665	674	687	1.01	1.03
618	CHN	660	670	682	1.01	1.03

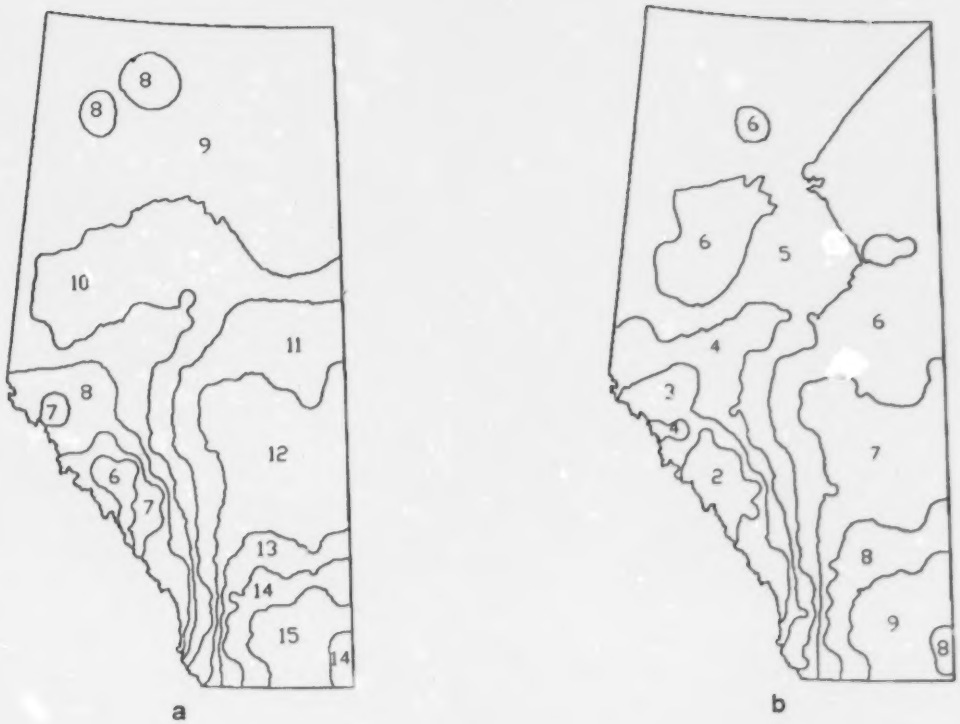
Appendix D-VI.3c (Continued).

Poly.#	Soil	SN6	SN5	SN4	SN5/SN6	SN4/SN6
619	FMT	666	675	686	1.01	1.03
620	MAB	663	689	699	1.04	1.05
621	TTH	0	706	717	0	0
622	TTH	664	708	719	1.07	1.08
623	ZRB	660	710	720	1.08	1.09
624	THA	0	730	740	0	0
626	SIL	0	672	680	0	0
627	MAB	658	679	688	1.03	1.05
628	BVL	661	686	696	1.04	1.05
629	SIL	660	683	692	1.03	1.05
631	MAB	667	691	703	1.04	1.06
632	MAB	668	710	723	1.06	1.08
633	MAB	671	720	733	1.07	1.09
634	MAB	665	695	707	1.04	1.06
635	MAB	668	703	716	1.05	1.07
637	MSN	670	723	736	1.08	1.1
638	ZRB	668	705	718	1.06	1.07
639	PUR	675	742	753	1.1	1.12
641	MAB	676	711	725	1.05	1.07
642	MAB	675	693	713	1.03	1.06
643	CHN	685	709	721	1.04	1.05
645	DLB	0	765	774	0	0
648	CFD	683	701	707	1.03	1.04
649	BVL	690	708	727	1.03	1.05
650	MAB	689	709	725	1.03	1.05
651	RDM	690	720	736	1.04	1.07
653	LET	686	734	750	1.07	1.09
654	PUY	689	715	743	1.04	1.08
655	DEL	0	775	788	0	0
656	PUY	0	753	765	0	0
657	LET	687	749	758	1.09	1.1
658	CMY	0	737	746	0	0
659	DEL	0	799	808	0	0
660	CVD	685	706	730	1.03	1.07
661	RDM	690	717	733	1.04	1.06
663	LET	0	737	747	0	0
664	RDM	0	729	742	0	0
666	PUR	0	743	754	0	0
667	LET	689	746	754	1.08	1.09
669	LOB	0	793	811	0	0
671	PHS	0	791	810	0	0
672	PED	0	796	818	0	0
673	MMO	0	805	828	0	0
675	BTN	0	813	837	0	0
676	CYG	0	810	834	0	0
677	BEN	0	806	830	0	0
680	PNC	0	823	843	0	0
681	CYG	0	810	830	0	0
682	BEN	0	821	843	0	0
683	HUB	0	830	855	0	0
684	CAR	0	832	852	0	0
686	LOB	0	806	825	0	0
689	CAR	0	831	853	0	0
690	RMY	0	821	844	0	0
691	HUB	0	842	864	0	0
692	BTN	0	837	861	0	0
693	RMY	0	815	840	0	0
694	HUB	0	821	847	0	0
695	BTN	0	821	848	0	0

Poly.#	Soil	SN6	SN5	SN4	SN5/SN6	SN4/SN6
696	BTN	0	824	849	0	0
698	MYW	0	825	849	0	0
699	HUB	0	824	847	0	0
702	CVL	0	827	851	0	0
703	HGV	0	825	847	0	0
705	MCO	0	823	841	0	0
708	MLA	0	827	847	0	0
709	COA	0	833	853	0	0
710	COA	0	825	848	0	0
711	COA	0	829	850	0	0
715	KVG	0	824	847	0	0

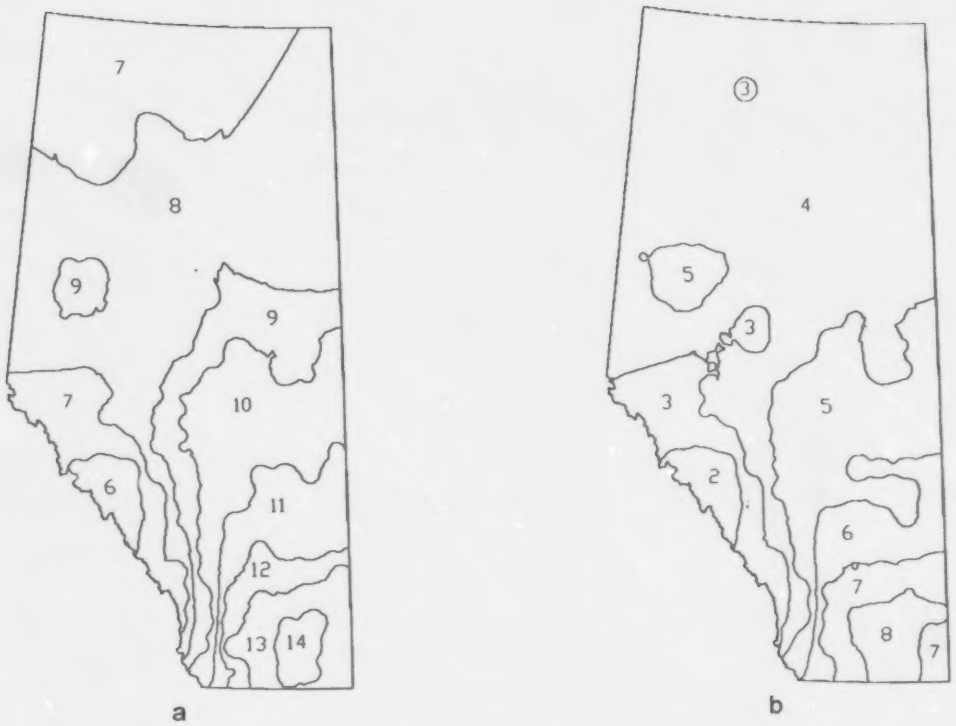
APPENDIX E

Model output maps of Alberta

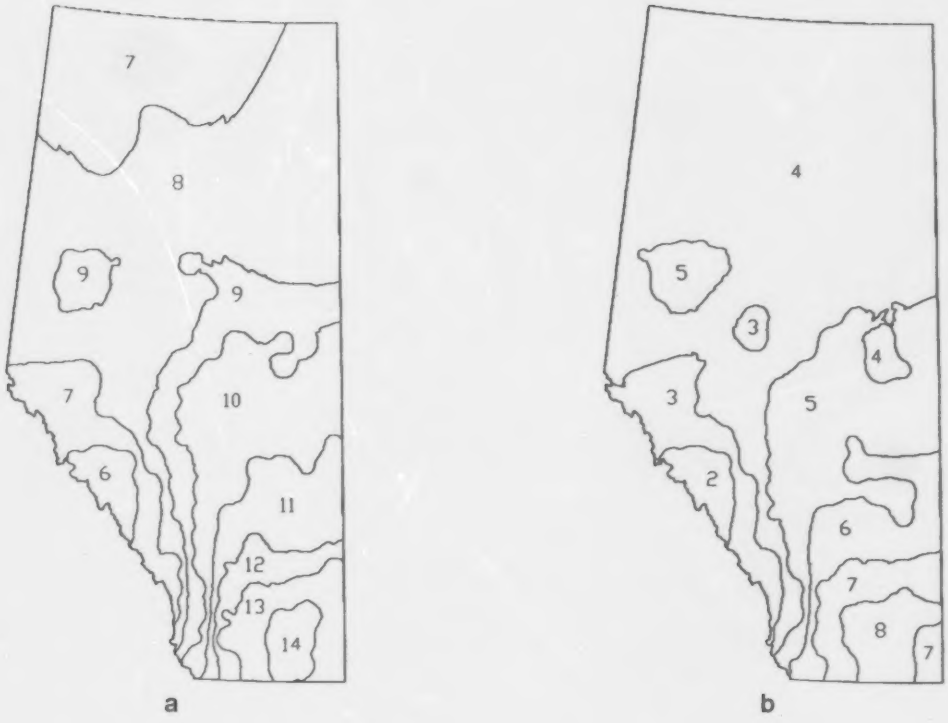


Appendix E-IV.1: Corn heat unit (CHU) distributions across Alberta for climate scenario (a=SN5) and historical climate (b=SN6); 1 = 900<CHU<1101; 2 = 1100<CHU<1301; 3 = 1300<CHU<1501; 4 = 1500<CHU<1701; 5 = 1700<CHU<1901; 6= 1900<CHU<2101; 7 = 2100<CHU<2301; 8 = 2300<CHU<2501; 9 = 2500<CHU<2701; 10 = 2700<CHU<2901; 11 = 2900<CHU<3101; 12 = 3100<CHU<3301; 13 = 3300<CHU<3501; 14 = 3500<CHU<3701; 15 = 3700<CHU<3901; 16 = 3900<CHU<4101.

Appendix E-IV.2a: Growing degree day (0°C base) distributions across Alberta for climate scenario (a=SN5) and historical climate (b=SN6); 1 = 900<GDD<1101; 2 = 1100<GDD<1301; 3 = 1300<GDD<1501; 4 = 1500<GDD<1701; 5 = 1700<GDD<1901; 6 = 1900<GDD<2101; 7 = 2100<GDD<2301; 8 = 2300<GDD<2501; 9 = 2500<GDD<2701; 10 = 2700<GDD<2901; 11 = 2900<GDD<3101; 12 = 3100<GDD<3301; 13 = 3300<GDD<3501; 14 = 3500<GDD<3701; 15 = 3700<GDD<3901; 16 = 3900<GDD<4101.



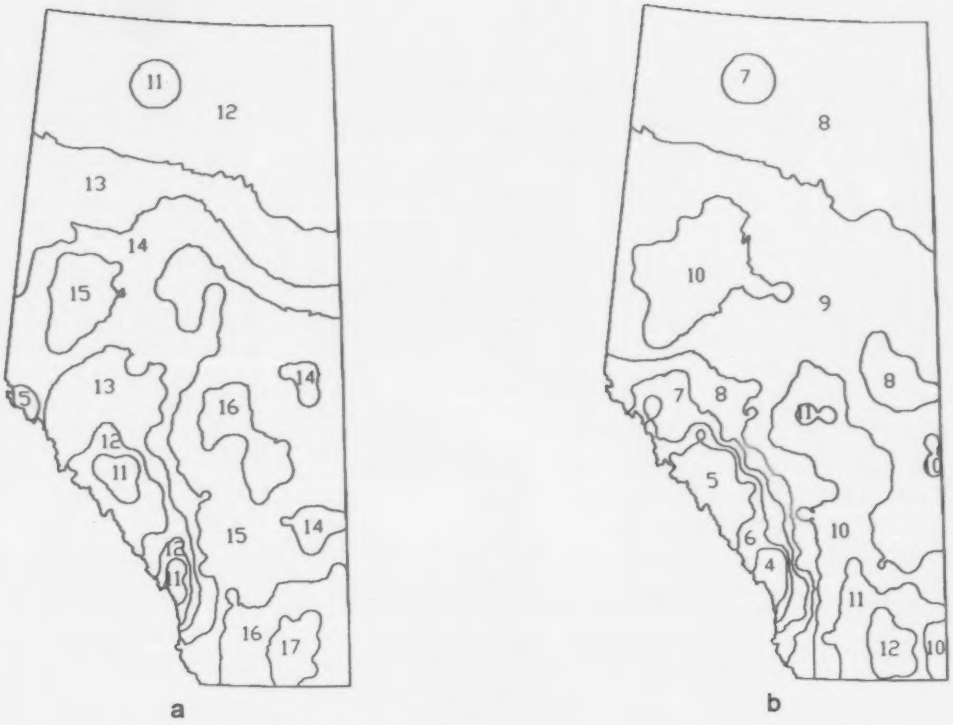
Appendix E-IV.2b: Growing degree day (5°C base) distributions across Alberta for climate scenario (a=SN5) and historical climate (b=SN6); 1 = 900<GDD<1101; 2 = 1100<GDD<1301; 3 = 1300<GDD<1501; 4 = 1500<GDD<1701; 5 = 1700<GDD<1901; 6 = 1900<GDD<2101; 7 = 2100<GDD<2301; 8 = 2300<GDD<2501; 9 = 2500<GDD<2701; 10 = 2700<GDD<2901; 11 = 2900<GDD<3101; 12 = 3100<GDD<3301; 13 = 3300<GDD<3501; 14 = 3500<GDD<3701; 15 = 3700<GDD<3901; 16 = 3900<GDD<4101.



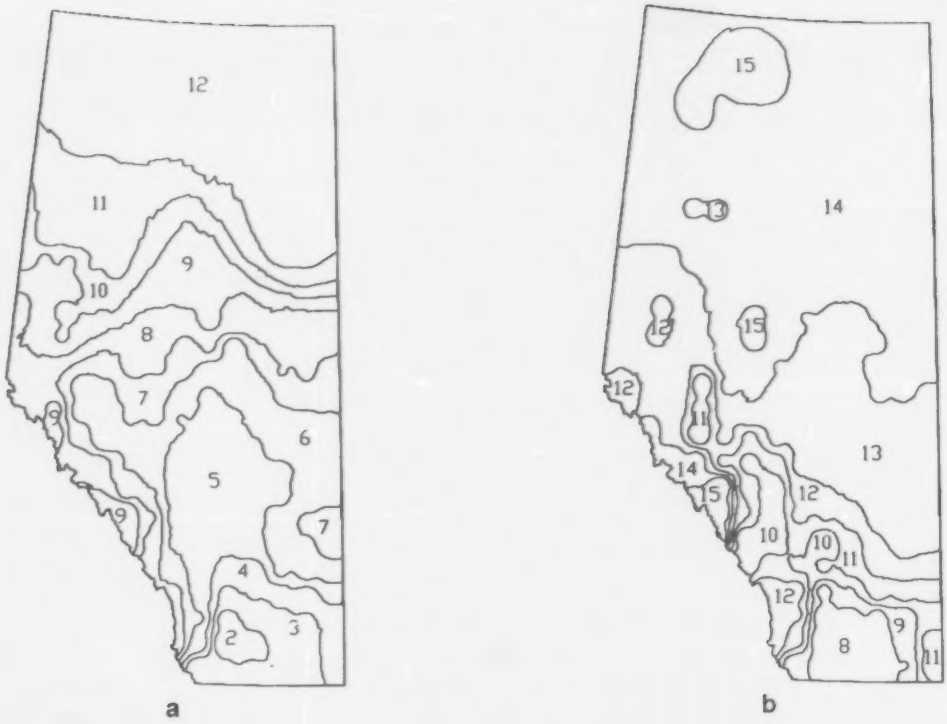
Appendix E-IV.2c: Growing degree day (8°C base) distributions across Alberta for climate scenario (a=SN5) and historical climate (b=SN6); 1 = 900<GDD<1101; 2 = 1100<GDD<1301; 3 = 1300<GDD<1501; 4 = 1500<GDD<1701; 5 = 1700<GDD<1901; 6 = 1900<GDD<2101; 7 = 2100<GDD<2301; 8 = 2300<GDD<2501; 9 = 2500<GDD<2701; 10 = 2700<GDD<2901; 11 = 2900<GDD<3101; 12 = 3100<GDD<3301; 13 = 3300<GDD<3501; 14 = 3500<GDD<3701; 15 = 3700<GDD<3901; 16 = 3900<GDD<4101.

Appendix E-IV.2d: Growing degree day (10°C base) distributions across Alberta for climate scenario (a=SN5) and historical climate (b=SN6); 1 = 900<GDD<1101; 2 = 1100<GDD<1301; 3 = 1300<GDD<1501; 4 = 1500<GDD<1701; 5 = 1700<GDD<1901; 6 = 1900<GDD<2101; 7 = 2100<GDD<2301; 8 = 2300<GDD<2501; 9 = 2500<GDD<2701; 10 = 2700<GDD<2901; 11 = 2900<GDD<3101; 12 = 3100<GDD<3301; 13 = 3300<GDD<3501; 14 = 3500<GDD<3701; 15 = 3700<GDD<3901; 16 = 3900<GDD<4101.

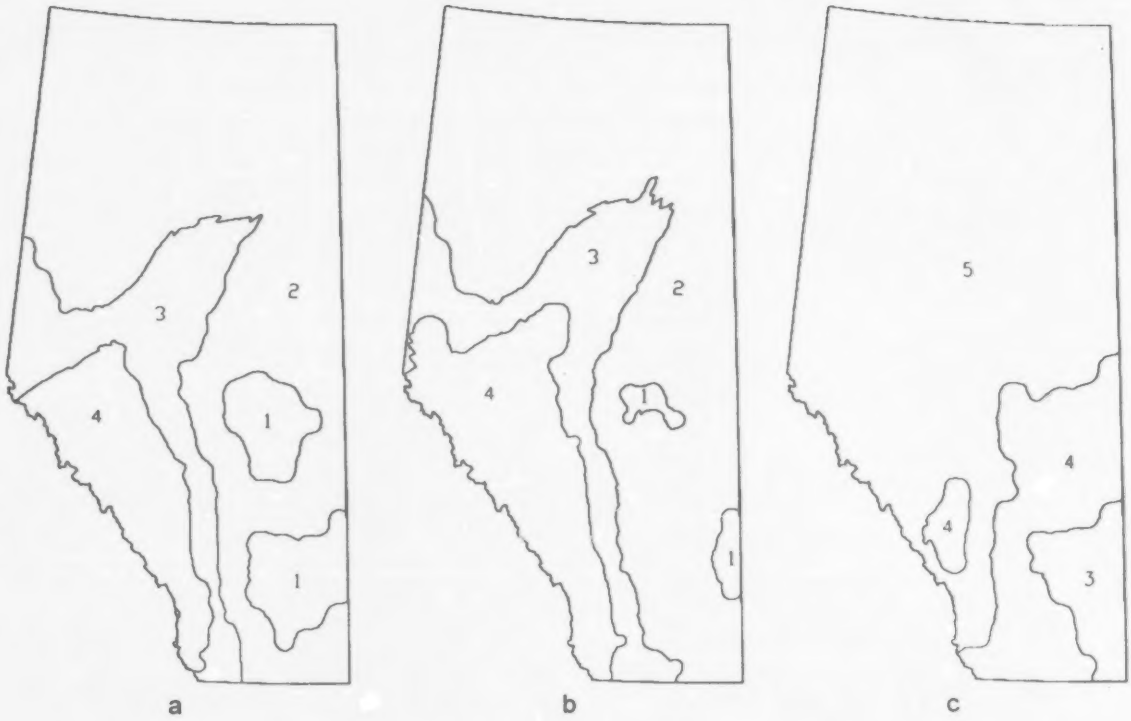
Appendix E-IV.3: Heating degree day (HDD) distributions across Alberta for climate scenario (a=SN5) and historical climate (b=SN6); 1 = 3400<HDD<3801; 2 = 3800<HDD<4201; 3 = 4200<HDD<4601; 4 = 4600<HDD<5001; 5 = 5000<HDD<5401; 6 = 5400<HDD<5801; 7 = 5800<HDD<6201; 8 = 6200<HDD<6601; 9 = 6600<HDD<7001; 10 = 7000<HDD<7401.



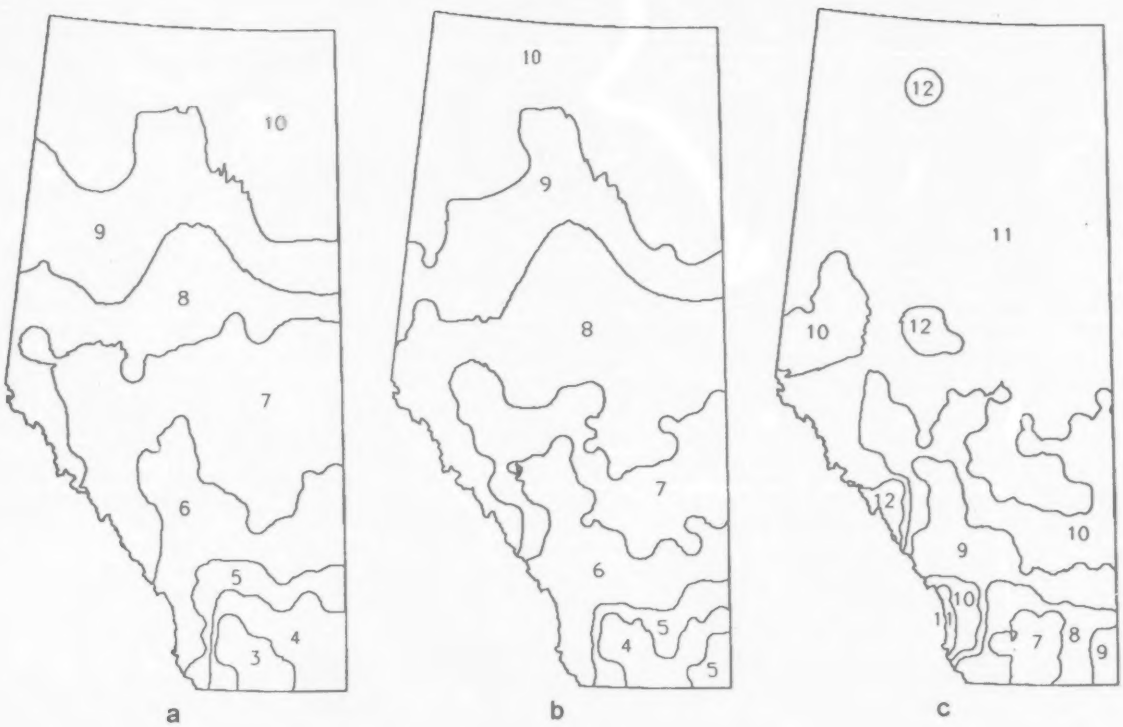
Appendix E-IV.4: Frost free day (FFD) distributions across Alberta for climate scenario (a=SN5) and historical climate (b=SN6); 1 = 74<FFD<82; 2 = 81<FFD<89; 3 = 88<FFD<96; 4 = 95<FFD<103; 5 = 102<FFD<110; 6 = 109<FFD<117; 7 = 116<FFD<124; 8 = 123<FFD<131; 9 = 130<FFD<138; 10 = 137<FFD<145; 11 = 144<FFD<152; 12 = 151<FFD<159; 13 = 158<FFD<166; 14 = 165<FFD<173; 15 = 172<FFD<180; 16 = 179<FFD<187; 17 = 186<FFD<194.



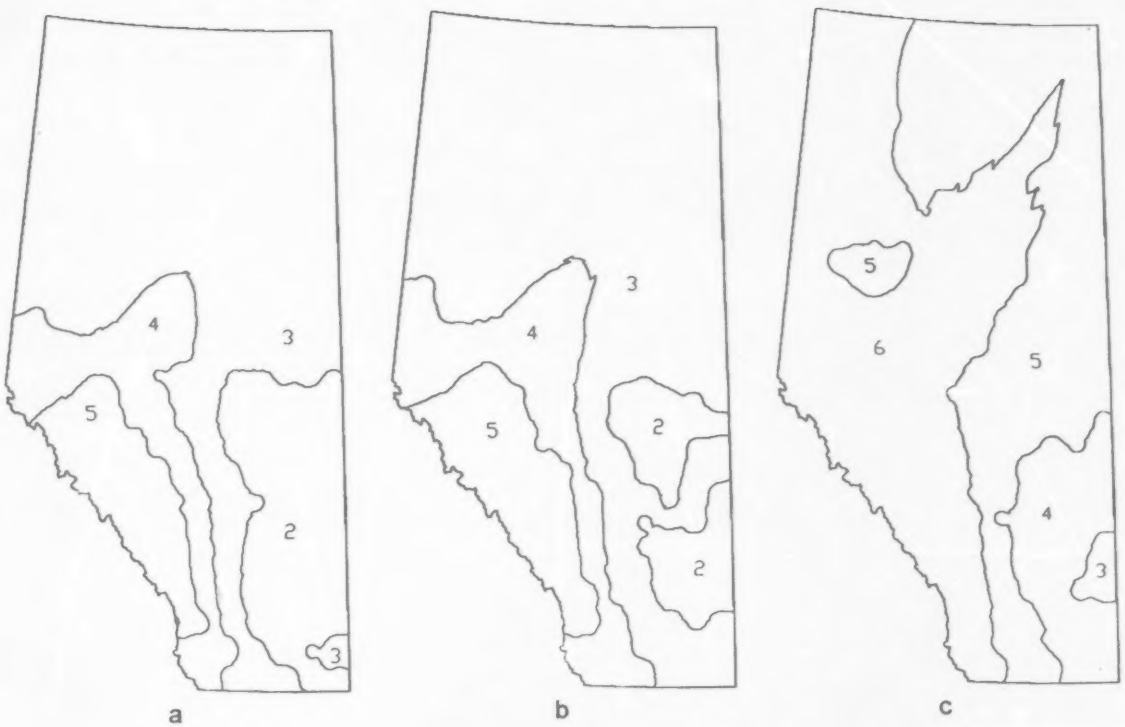
Appendix E-IV.5: Winter wheat regrowth (RGRW; Julian day) distributions across Alberta for climate scenario (a=SN5) and historical climate (b=SN6); 1= 48<RGRW<56; 2 = 55<RGRW<63; 3 = 62<RGRW<70; 4 = 69<RGRW<77; 5 = 76<RGRW<84; 6 = 83<RGRW<91; 7 = 90<RGRW<98; 8 = 97<RGRW<105; 9 = 104<RGRW<112; 10 = 111<RGRW<119; 11 = 118<RGRW<126; 12 = 125<RGRW<133; 13 = 132<RGRW<140; 14 = 139<RGRW<147; 15 = 146<RGRW<154.



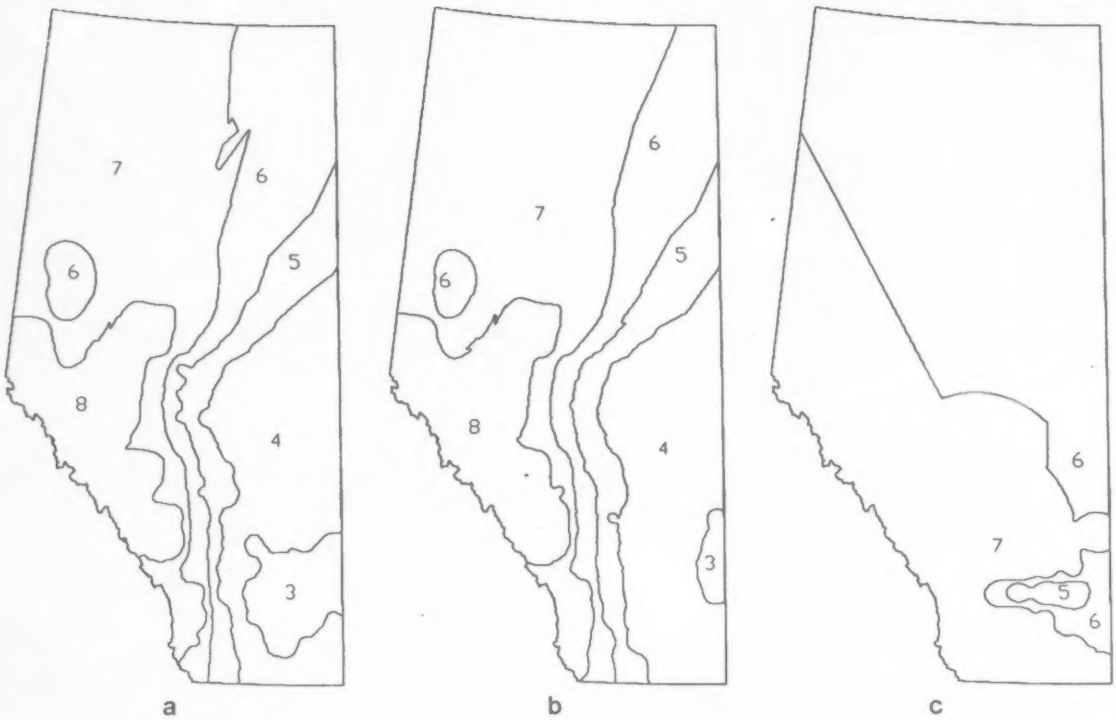
Appendix E-V.2a: Canola growth duration (GD) distributions across Alberta for climate scenarios (a=SN4; b=SN5) and historical climate (c=SN6); 1 = GD<76; 2 = 75<GD<83; 3 = 82<GD<90;4 = 89<GD<97; 5 = 96<GD>104; 6 = 103<GD<111; 7 = 110<GD<118; 8 = 117<GD<125; 9 = 124<GD<132; 10 = 131<GD>139; 11 = 138<GD<146; 12 = 147<GD<155; 13 = 154<GD.



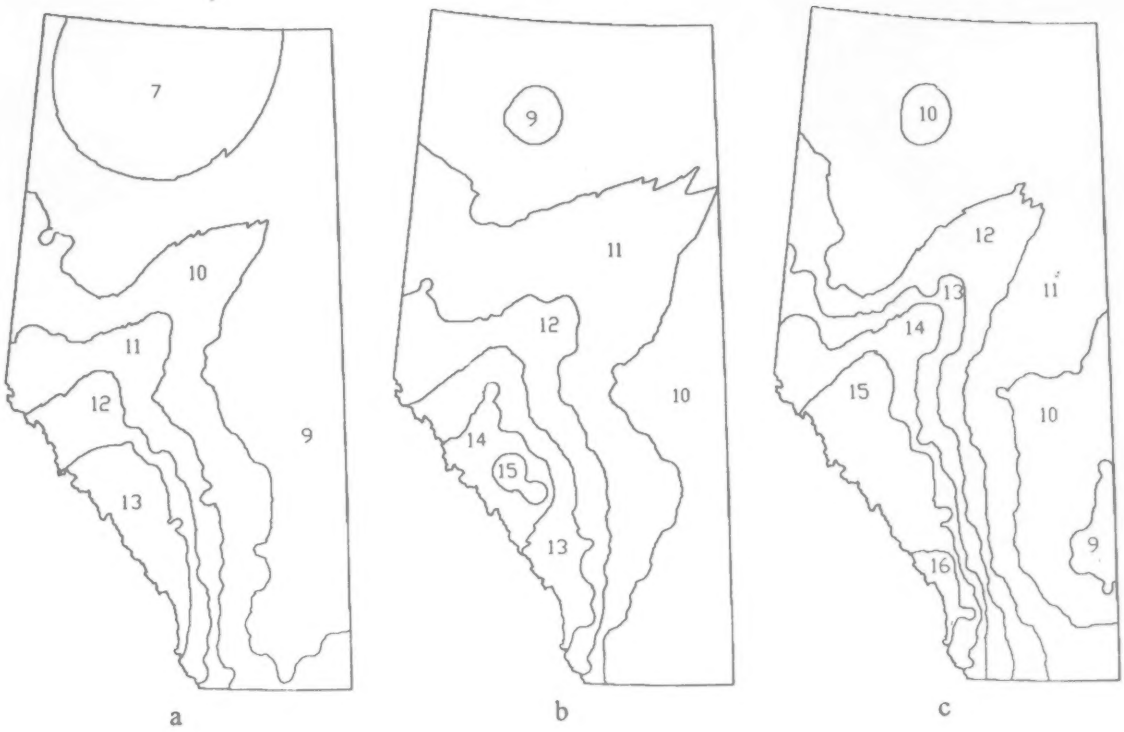
Appendix E-V.1: Spring wheat seeding date (SD; Julian date) distributions across Alberta for climate scenarios (a=SN4; b=SN5) and historical climate (c=SN6); 1 = SD<78; 2 = 77<SD<85; 3 = 84<SD<92; 4 = 91<SD<99; 5 = 98<SD>106; 6 = 105<SD<113; 7 = 112<SD<120; 8 = 119<SD<127; 9 = 126<SD<134; 10 = 133<SD>141; 11 = 140<SD<148; 12 = 147<SD<155; 13 = 154<SD.



Appendix E-V.2b: Spring wheat growth duration (GD) distributions across Alberta for climate scenarios (a=SN4; b=SN5) and historical climate (c=SN5) and ; 1 = GD<76; 2 = 75<GD<83; 3 = 82<GD<90;4 = 89<GD<97; 5 = 96<GD>104; 6 = 103<GD<111; 7 = 110<GD<118; 8 = 117<GD<125; 9 = 124<GD<132; 10 = 131<GD>139; 11 = 138<GD<146; 12 = 147<GD<155; 13 = 154<GD.

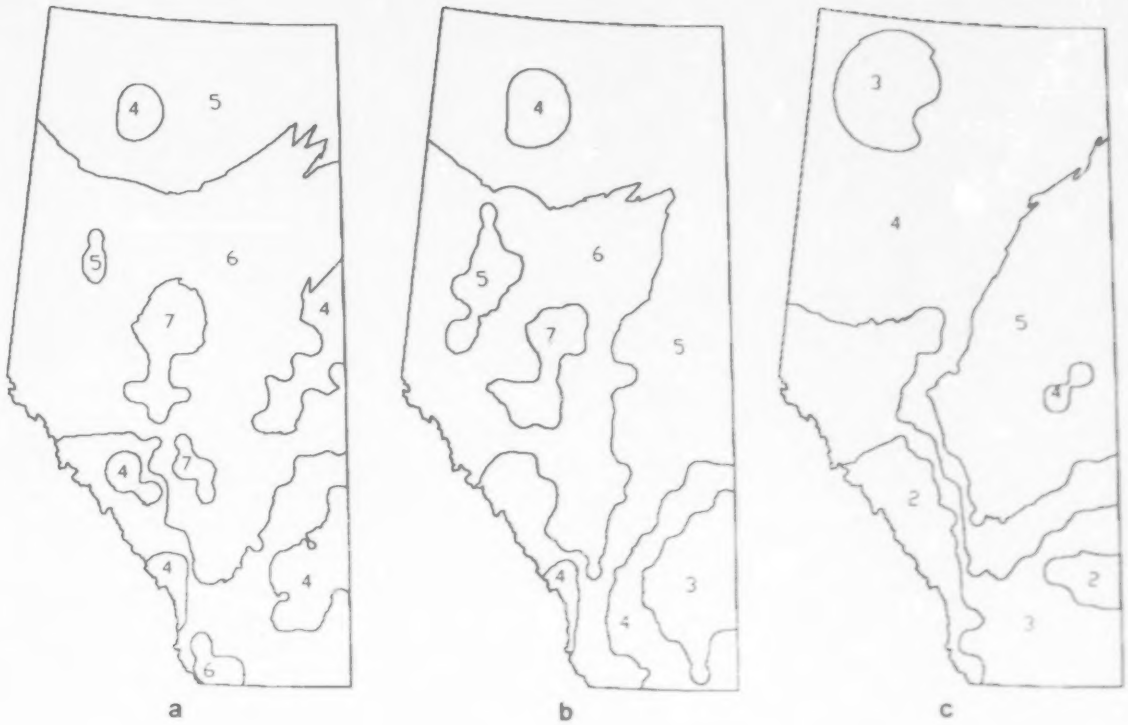


Appendix E-V.2c: Corn growth duration (GD) distributions across Alberta for climate scenarios (a=SN4; b=SN5) and historical climate (c=SN5); 1 = GD<76; 2 = 75<GD<83; 3 = 82<GD<90;4 = 89<GD<97; 5 = 96<GD>104; 6 = 103<GD<111; 7 = 110<GD<118; 8 = 117<GD<125; 9 = 124<GD<132; 10 = 131<GD>139; 11 = 138<GD<146; 12 = 147<GD<155; 13 = 154<GD.

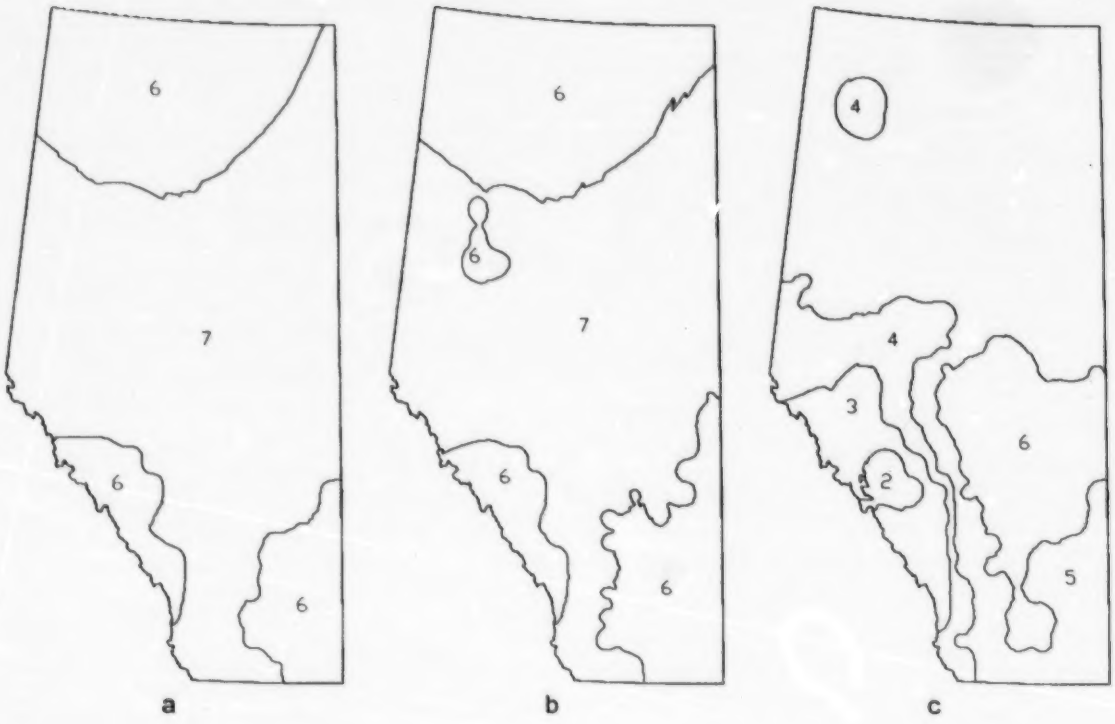


Appendix E-V.2d: Winter wheat growth duration (GD) distributions across Alberta for climate scenarios (a=SN4; b=SN5) and historical climate (c=SN6); 1 = GD<76; 2 = 75<GD<83; 3 = 82<GD<90;4 = 89<GD<97; 5 = 96<GD>104; 6 = 103<GD<111; 7 = 110<GD<118; 8 = 117<GD<125; 9 = 124<GD<132; 10 = 131<GD>139; 11 = 138<GD<146; 12 = 147<GD<155; 13 = 154<GD.

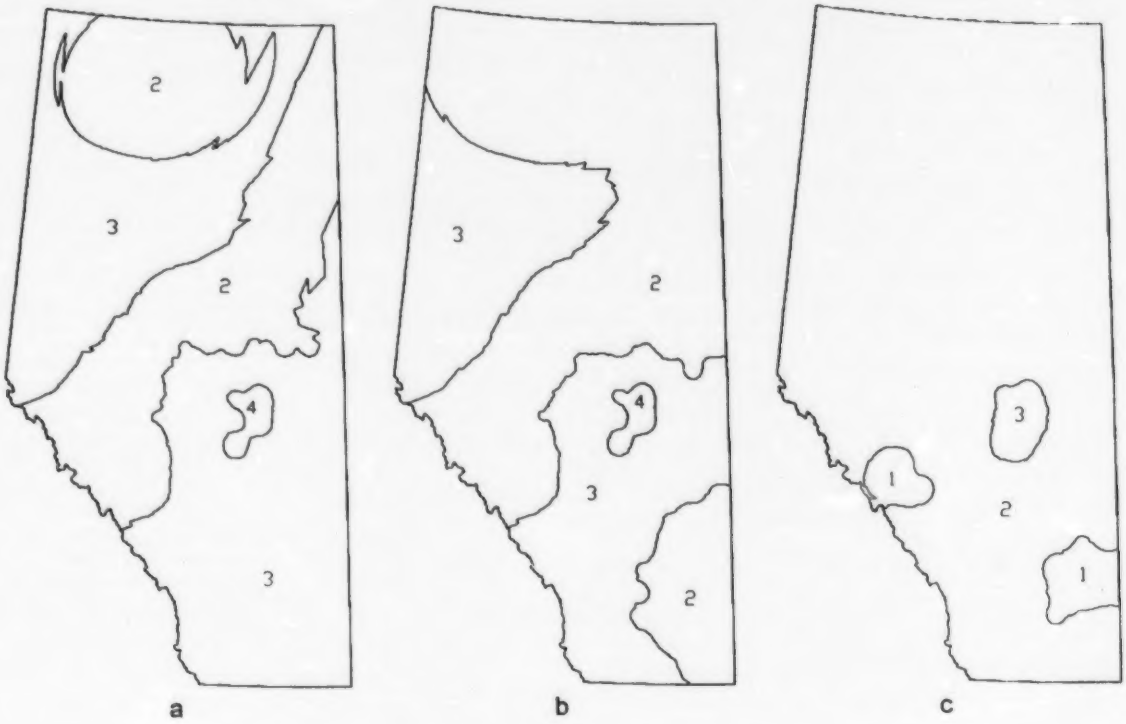
Appendix E-VI.1a: Dryland canola yield (g/m^2) distributions across Alberta for climate scenarios (a=SN4; b=SN5) and historical climate (c=SN6); 1 = yield<101; 2 = 100<yield<151; 3 = 150<yield<201;4 = 200<yield<251; 5 = 250<yield<301; 6 = 300<yield<351; 7 = 350<yield<401; 8 = 400<yield<451; 9 = 450<yield<501; 10 = 500<yield<551; 11 = 550<yield<601; 12 = 600<yield<651; 13 = 650<yield.



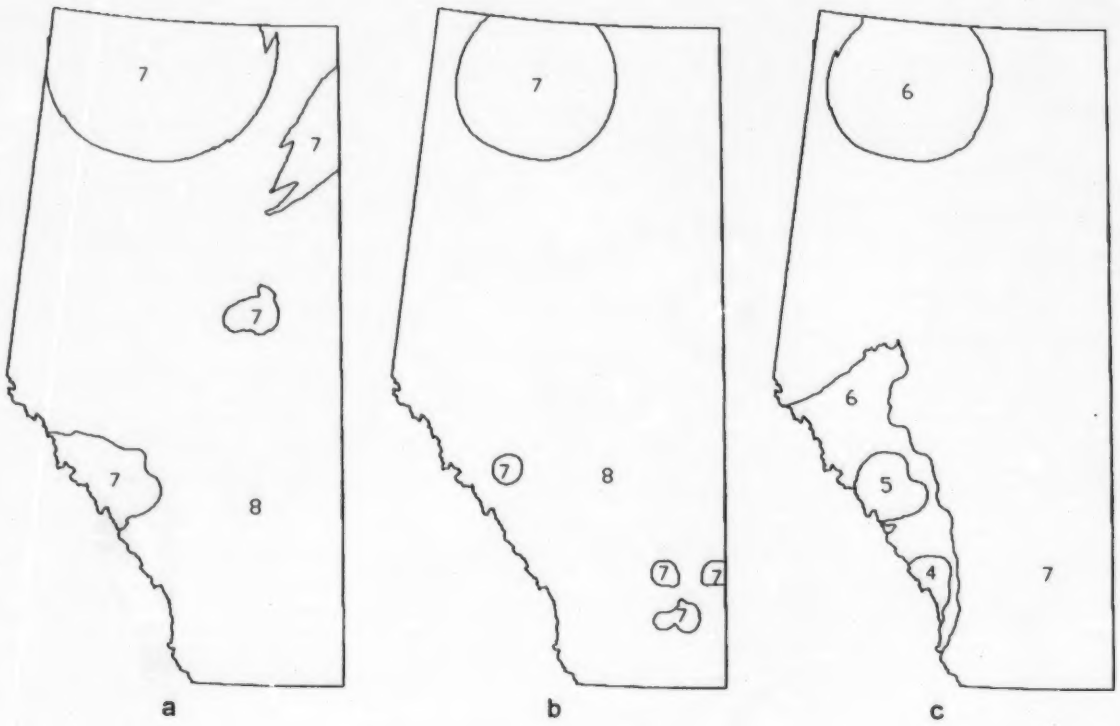
Appendix E-VI.1b: Fallow-canola yield (g/m^2) distributions across Alberta for climate scenarios (a=SN4; b=SN5) and historical climate (c=SN6); 1 = yield<101; 2 = 100<yield<151; 3 = 150<yield<201;4 = 200<yield<251; 5 = 250<yield<301; 6 = 300<yield<351; 7 = 350<yield<401; 8 = 400<yield<451; 9 = 450<yield<501; 10 = 500<yield<551; 11 = 550<yield<601; 12 = 600<yield<651; 13 = 650<yield.



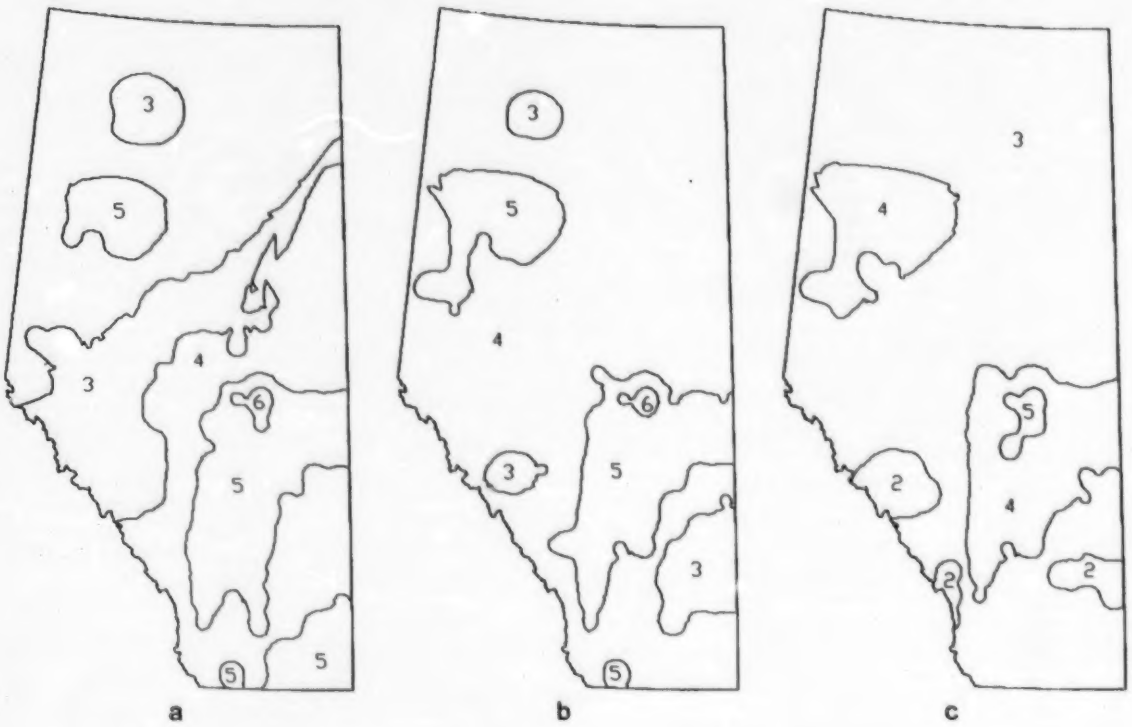
Appendix E-VI.1c: Irrigated canola yield (g/m^2) distributions across Alberta for climate scenarios (a=SN4; b=SN5) and historical climate (c=SN6); 1 = yield<101; 2 = 100<yield<151; 3 = 150<yield<201;4 = 200<yield<251; 5 = 250<yield<301; 6 = 300<yield<351; 7 = 350<yield<401; 8 = 400<yield<451; 9 = 450<yield<501; 10 = 500<yield<551; 11 = 550<yield<601; 12 = 600<yield<651; 13 = 650<yield.



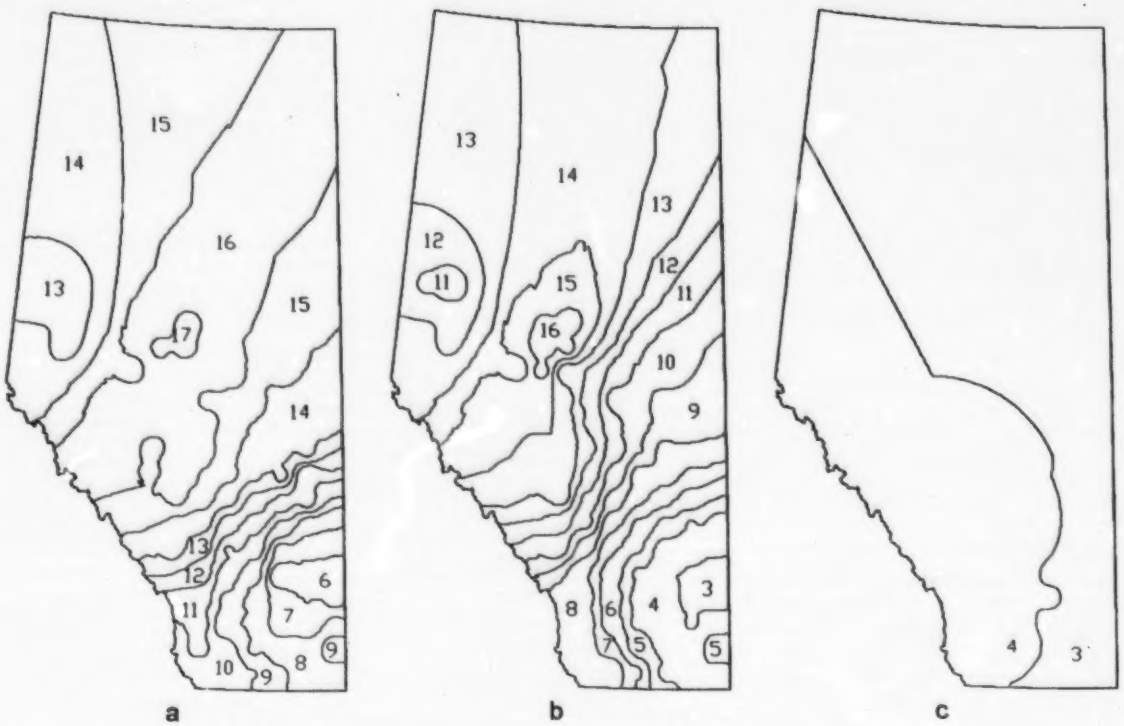
Appendix E-VI.2a: Dryland spring wheat yield (g/m^2) distributions across Alberta for climate scenarios (a = SN4; b = SN5) and historical climate (c = SN6); 1 = yield<101; 2= 100<yield<151; 3 = 150<yield<201; 4= 200<yield<251; 5 = 250<yield<301; 6= 300<yield<351; 7 = 350<yield<401; 8= 400<yield<451; 9 = 450<yield<501; 10= 500<yield<551; 11 = 550<yield<601; 12= 600<yield<651; 13 = 650<yield.



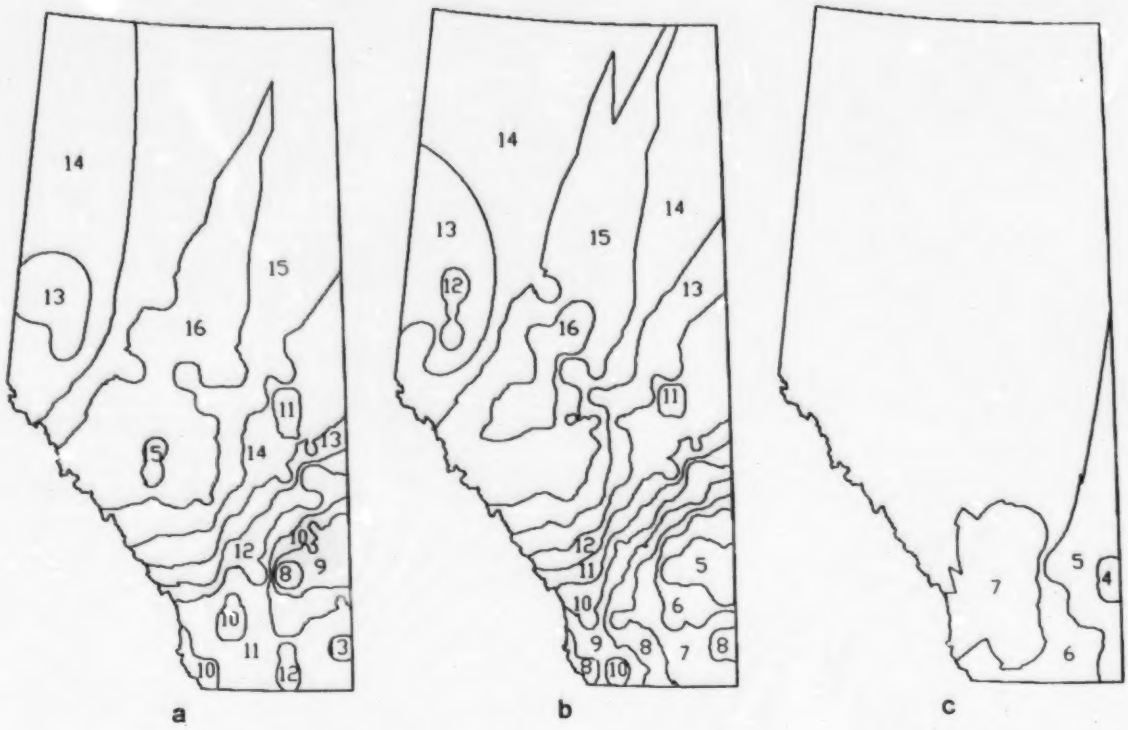
Appendix E-VI.2b: Irrigated spring wheat yield (g/m^2) distributions across Alberta for climate scenarios (a = SN4; b = SN5) and historical climate (c = SN6); 1 = yield<101; 2= 100<yield<151; 3 = 150<yield<201; 4= 200<yield<251; 5 = 250<yield<301; 6= 300<yield<351; 7 = 350<yield<401; 8= 400<yield<451; 9 = 450<yield<501; 10= 500<yield<551; 11 = 550<yield<601; 12= 600<yield<651; 13 = 650<yield.



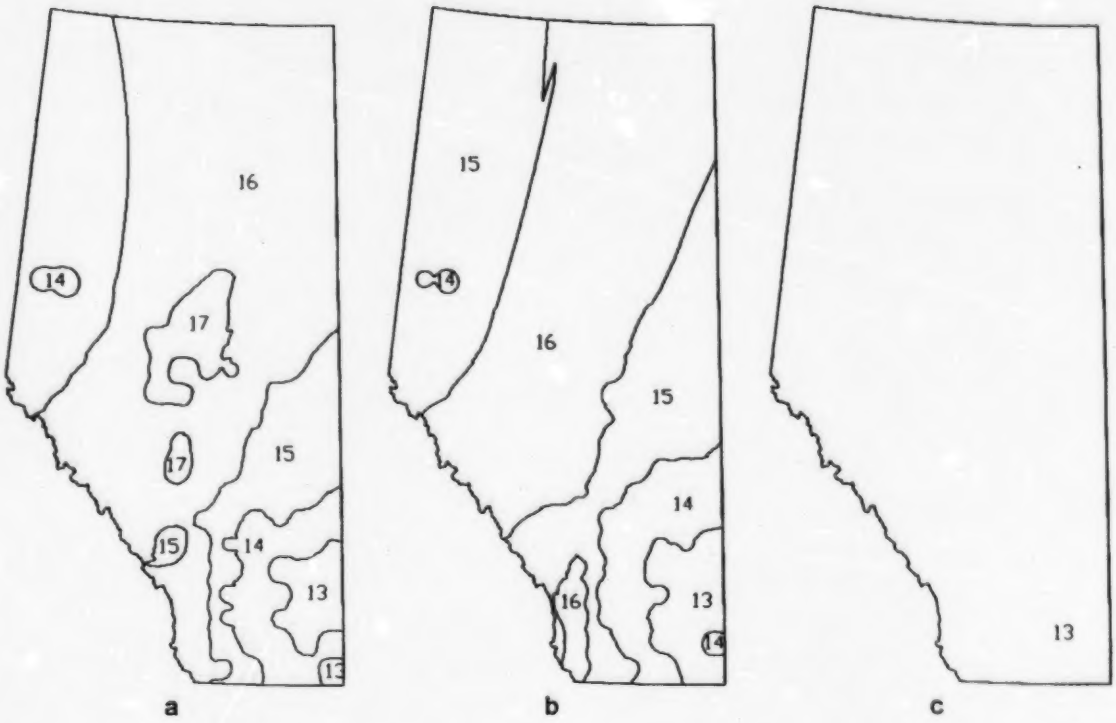
Appendix E-VI.2c: Fallow-spring wheat yield (g/m^2) distributions across Alberta for climate scenarios (a=SN4; b=SN5) and historical climate (c=SN6); 1 = yield<101; 2 = 100<yield<151; 3 = 150<yield<201;4 = 200<yield<251; 5 = 250<yield<301; 6 = 300<yield<351; 7 = 350<yield<401; 8 = 400<yield<451; 9 = 450<yield<501; 10 = 500<yield<551; 11 = 550<yield<601; 12 = 600<yield<651; 13 = 650<yield.



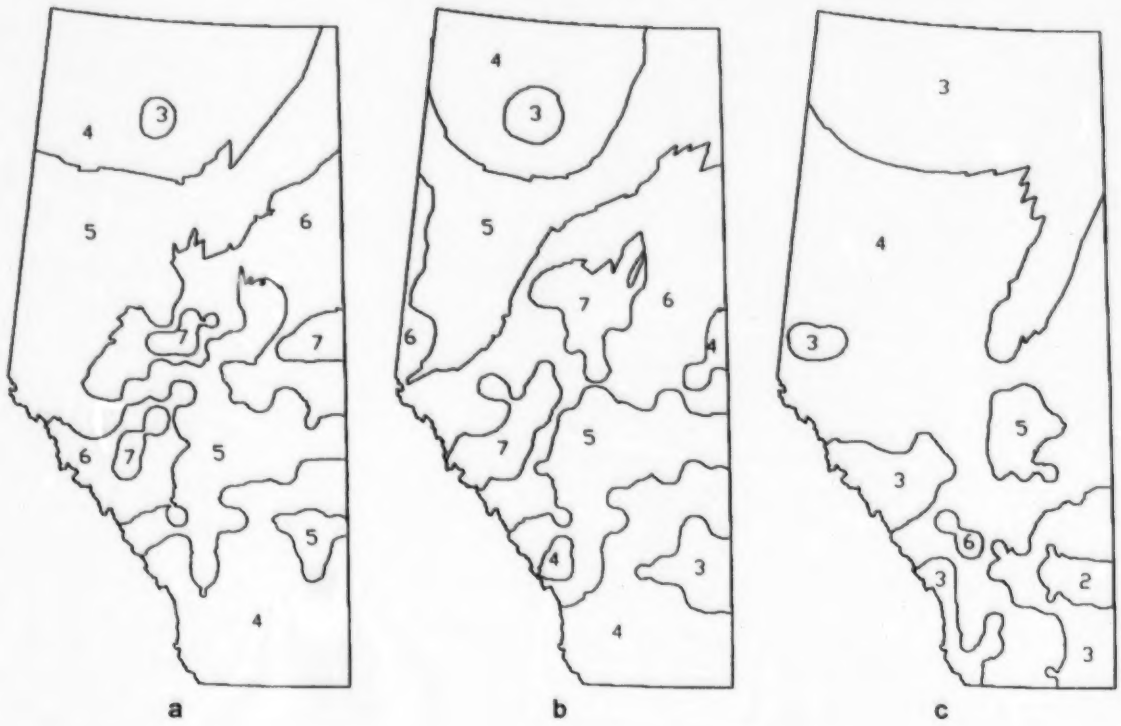
Appendix E-VI.3a: Dryland corn yield (g/m^2) distributions across Alberta for climate scenarios (a=SN4; b=SN5) and historical climate (c=SN6); 1 = yield<101; 2 = 100<yield<151; 3 = 150<yield<201;4 = 200<yield<251; 5 = 250<yield<301; 6 = 300<yield<351; 7 = 350<yield<401; 8 = 400<yield<451; 9 = 450<yield<501; 10 = 500<yield<551; 11 = 550<yield<601; 12 = 600<yield<651; 13 = 650<yield<701; 14 = 700<yield<751; 15 = 750<yield<801; 16 = 800<yield<851; 17 = 850<yield<901.



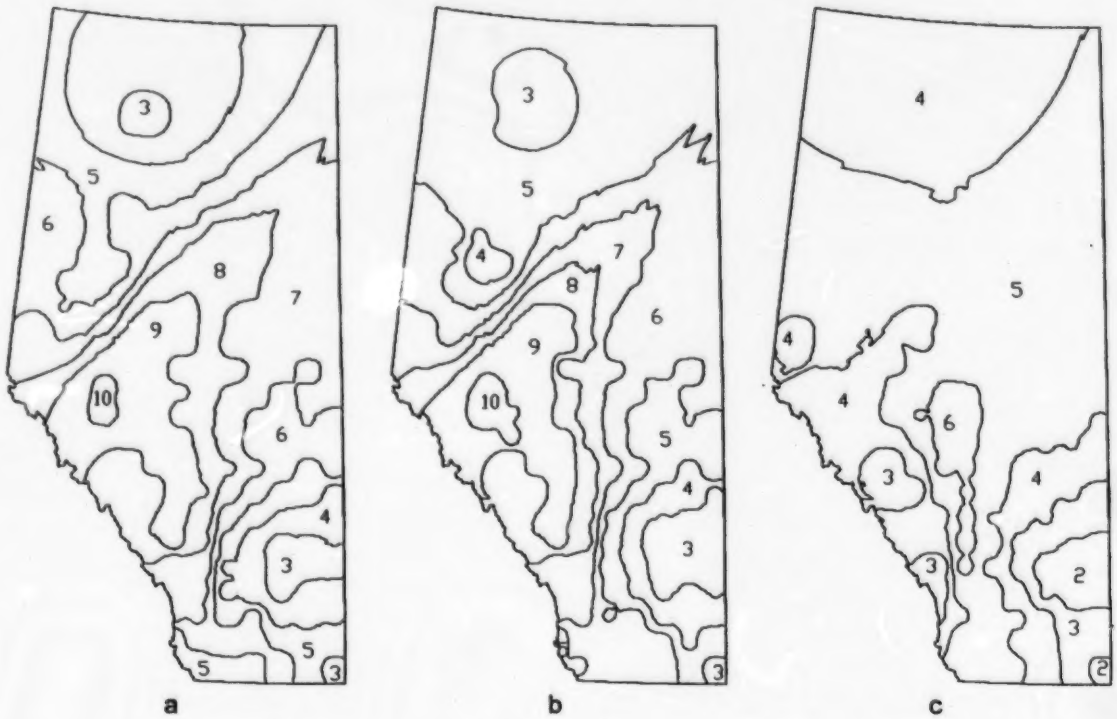
Appendix E-VI.3b: Fallow-corn yield (g/m^2) distributions across Alberta for climate scenarios (a=SN4; b=SN5) and historical climate (c=SN6); 1 = yield<101; 2 = 100<yield<151; 3 = 150<yield<201;4 = 200<yield<251; 5 = 250<yield<301; 6 = 300<yield<351; 7 = 350<yield<401; 8 = 400<yield<451; 9 = 450<yield<501; 10 = 500<yield<551; 11 = 550<yield<601; 12 = 600<yield<651; 13 = 650<yield<701; 14 = 700<yield<751; 15 = 750<yield<801; 16 = 800<yield<851; 17 = 850<yield<901.



Appendix E-VI.3c: Irrigated corn yield (g/m^2) distributions across Alberta for climate scenarios (a=SN4; b=SN5) and historical climate (c=SN6); 1 = yield<101; 2 = 100<yield<151; 3 = 150<yield<201;4 = 200<yield<251; 5 = 250<yield<301; 6 = 300<yield<351; 7 = 350<yield<401; 8 = 400<yield<451; 9 = 450<yield<501; 10 = 500<yield<551; 11 = 550<yield<601; 12 = 600<yield<651; 13 = 650<yield<701; 14 = 700<yield<751; 15 = 750<yield<801; 16 = 800<yield<851; 17 = 850<yield<901.



Appendix E-VI.4: Fallow-winter wheat yield (g/m^2) distributions across Alberta for climate scenarios (a=SN4; b=SN5) and historical climate (c=SN6); 1 = yield<101; 2 = 100<yield<151; 3 = 150<yield<201;4 = 200<yield<251; 5 = 250<yield<301; 6 = 300<yield<351; 7 = 350<yield<401; 8 = 400<yield<451; 9 = 450<yield<501; 10 = 500<yield<551; 11 = 550<yield<601; 12 = 600<yield<651; 13 = 650<yield.



Appendix E-VI.5: Crested wheatgrass yield (g/m^2) distributions across Alberta for climate scenarios (a=SN4; b=SN5) and historical climate (c=SN6); 1 = yield<101; 2 = 100<yield<201; 3 = 200<yield<301;4 = 300<yield<401; 5 = 400<yield<501; 6 = 500<yield<601; 7 = 600<yield<701; 8 = 700<yield<801; 9 = 800<yield<901; 10 = 1001<yield<1101; 11 = 1100<yield.